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ABSTRACT

The Rand Corporation has been doing research on closed-circuit television systems to aid the partially sighted since 1966. The current experimental system enhances the image electronically to provide a magnified image that is brighter and has greater contrast than the object being observed. The system also incorporates an easily movable platform for the material being observed or read. Test results indicate that persons with visual acuity as low as 20/1300 are able to read printed or handwritten material with the aid of the closed-circuit television system. Systems based on this research are now commercially available and have been purchased by schools, libraries, rehabilitation agencies and private individuals. (Author/RH)

SRS

SCOPE OF INTEREST NOTICE

ADVANCES IN CLOSED CIRCUIT TV SYSTEMS FOR THE PARTIALLY SIGHTED

S. M. Genensky, Project Director
H. E. Petersen, H. L. Moshin, R. W. Clewett, R. I. Yoshimura

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April 1972

A Final Report prepared under Research Grant (Project No. 14-P-55285/9) from Social and Rehabilitation Service U. S. Department of Health, Education, and Welfare

Rand

HIGHLIGHTS

1. The Rand Corporation has been doing research on CCTV systems for the partially sighted since 1966. Such instruments are superior to pure optical devices because they permit electronic enhancement, which produces on a monitor screen a magnified image that is brighter and has greater contrast than the object being observed. Further, they can provide contrast reversal—for example, the ability to view white characters on a black background when working with ordinary print or writing.

2. Test results indicate that persons with corrected visual acuity in their better eye no greater than 20/50 and some with acuity as low as 20/1300 are able to read printed or handwritten material with the aid of a CCTV system. Many of them are unable to carry out these operations otherwise.

3. Test results using RANDSIGHT I equipped with an "X-Y Platform" (see text) show the following:

- 45 of the 81 subjects tested read aloud in excess of 30 words per minute after only a few minutes' experience with RANDSIGHT I. Our experience indicates that, with few exceptions, reading rates can be expected to more than double over time.
- Reading rates as high as 190 words per minute were recorded.
- At least 39 of the 60 subjects tested for writing could write clearly and legibly.

4. An X-Y Platform and contrast reversal are indispensable features of a well-designed CCTV system. Other important features of a CCTV system are discussed in the report.

5. A simple test using transparencies and a lightbox is described that should assist medical and paramedical personnel in ascertaining whether the subject could benefit from a CCTV system.

6. RANDSIGHT II is an experimental CCTV system designed expressly for the partially sighted, but it incorporates additional features—such as automatic, or foot- or hand-operated controls of the camera movement—which may also benefit those with limb impairments.

7. There is no x-ray hazard from black-and-white TV operating at acceleration voltages up to 19 kilovolts.

8. CCTV systems based on the research reported here are commercially available and have been purchased by schools, libraries, rehabilitation agencies, and private individuals.

9. These CCTV systems are now:

- Helping students to work efficiently with ordinary study materials.
- Assisting persons of working age to obtain or retain jobs.
- Permitting the elderly to read, write, and perform other tasks essential to their independence and social adjustment.

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PREFACE

Since 1966, The Rand Corporation has been involved in the design, fabrication, and informal testing of closed circuit TV (CCTV) systems that enable many persons with severely impaired vision to read, write, and perform other operations requiring precise eye-hand coordination.

Initially financed by Rand itself, this work has since 1970 been mainly funded by the Social and Rehabilitation Service of the U.S. Department of Health, Education, and Welfare. Some support has also been provided by donations from private citizens interested in this research. Rand has also continued to support part of the project with its own funds.

The purpose of this final report to SRS is to review the work accomplished during the period May 1, 1970, to April 30, 1972, and to indicate plans for future work in this area.

One of the main achievements during this period has been the development of a CCTV system with several novel features which we call RANDSIGHT Ⓣ II. The designation "II" refers to the fact that an earlier instrument, RANDSIGHT I, had been designed and built solely with Rand support prior to the start of our SRS grant. The present report describes in detail the mechanical and electronic features of RANDSIGHT II and its operation. Another major achievement was the design of an easily maneuverable platform, which when incorporated in CCTV systems improves operation and reduces cost. The report goes on to note that tests have been conducted to ascertain that users of such systems (operating at acceleration voltages not exceeding 19 kv) will not be exposed to harmful levels of x-radiation. Further work reported here concerns largely successful tests conducted in the use of a modified RANDSIGHT I system by partially sighted persons, research on electronic image enhancement and contrast reversal, and development of a simple test to determine whether a CCTV system could assist a partially sighted person in reading printed and handwritten materials. Next, the report proposes some criteria for the design of CCTV systems for the partially sighted. Finally, it reviews research conducted elsewhere on such systems.

Ⓣ RANDSIGHT is the Certification Mark of The Rand Corporation.

Rand's research on reading and writing aids for the partially sighted is of great significance to the rehabilitation of many persons legally classified as blind. Estimates of the number of legally blind people in the United States vary, but on the evidence available we conclude that they number about 400,000. More than 80 percent of the legally blind are believed to have some residual vision. We estimate that at least 60 percent of the 400,000 have enough residual vision to potentially benefit from the use of a CCTV system. In addition, there are about 600,000 literate Americans not legally blind but unable to read a newspaper even with the aid of eyeglasses. This group is even more likely to be aided by CCTV systems. Thus, the total population that might benefit from such systems probably exceeds 800,000.

An indication of the strong interest in Rand's work in this area was provided by the response to an article in the *Reader's Digest* in January 1971 on our RANDSIGHT research. As a result of this article, we received over 5000 letters, cards, and telephone calls from people seeking aid for themselves, their patients, or friends and relatives. Over 120 partially sighted people visited Rand in person. It was from these visitors that we obtained the experimental results described in this report.

Another important indication of the interest and value of our RANDSIGHT research is that hundreds of CCTV systems, based in large measure on the results of our research, have been produced and sold to government agencies and private individuals and are being used successfully in schools, in libraries, on the job, and in the home.

Neither The Rand Corporation nor the project staff has any financial interest in any company that manufactures, distributes, or sells closed circuit TV systems for the partially sighted. Rand makes the results of its research freely available to any person or organization interested in helping the visually impaired.

ACKNOWLEDGMENTS

The authors wish to thank G. W. Dietrich and O. Garza for the fabrication of RANDSIGHT II and our X-Y Platforms. The quality of construction of these devices is due in large measure to their competence.

The authors thank their former colleagues R. A. Matthews and H. Steingold for their contributions to early instrument design. They also thank A. C. Lucero for modifying our TV monitors, J. Beavers for producing the lightbox transparencies and the photographs for this report, G. N. Lucas for preparing the circuit diagrams, and M. R. Davis for his support and interest.

We are indebted to G. H. Fisher and C. Gazley, Jr. for reading a draft of this report and giving us their suggestions and criticisms. The incorporation of many of their suggestions and the heeding of many of their criticisms have significantly improved the final product. We are also appreciative of the careful and competent editing provided by E. T. Gernert, O. Hoeffding, and M. A. Palmatier.

A special thanks is due to M. Wray who helped us cope with the thousands of letters and calls generated by the *Reader's Digest* article on our RANDSIGHT research and who very patiently typed various drafts of this report.

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I. INTRODUCTION AND SUMMARY

CLOSED CIRCUIT TV FOR THE PARTIALLY SIGHTED

The Rand Corporation has been working for the past six years on the design, fabrication, and informal testing of closed circuit TV (CCTV) systems for the partially sighted.[1] These instruments permit a large fraction of the legally blind population, as well as persons who have severe visual impairment, to read printed and handwritten material, to write with a pen or pencil, and to carry out other operations that require precise eye-hand coordination.[2] Over the past two years, more than 120 partially sighted people have tried out our CCTV systems. They ranged in age from 5 to 90 and had a wide variety of eye disorders, including macular degeneration, retinitis pigmentosa, optic nerve atrophy, and diabetic retinopathy. *Many of these people are unable to read printed or handwritten material or to write with a pen or pencil without the aid of a CCTV system.*

The exact number of legally blind people in America is not known. However, based on available data, we have concluded that they number about 400,000.[3] According to Trouern-Trend, more than 80 percent of the legally blind have some residual vision, and we estimate that at least 60 percent of them have enough residual vision to benefit from the use of a CCTV system. In addition, about a million literate Americans are unable to read a newspaper even with the aid of eyeglasses. Therefore, under the assumptions that (1) there are 400,000 legally blind in America, (2) 60 percent of them could benefit from a CCTV system, (3) the legally

[1] The term *partially sighted* as used here includes all the visually impaired who are *functionally sighted* or *functionally sighted with aided mobility*. These terms are carefully defined in Ref. 1. Roughly speaking, partially sighted refers to those whose visual acuity in their better eye does not exceed 20/70 even with the aid of corrective lenses, but who can visually resolve printed material with or without the additional aid of optical or electro-optical devices. It also includes those whose visual acuity exceeds 20/70 but whose visual field is greatly restricted in size and geometry.

[2] Earlier Rand reports on this work are referenced in [1], [2], [3], [4], [5], and [6]. Bracketed numbers refer to the references that are found at the end of the text.

[3] K. Trouern-Trend [7] estimates the legally blind population of the United States to be about 300,000. The National Society for Prevention of Blindness (in "Estimated Statistics on Blindness in Vision Problems") estimates it to be about 400,000. N. Bier [8] estimates that it is "very much larger" than 300,000 (based on an estimated U.S. population of 180 million). Various ophthalmologists and optometrists have informed us of their conjectural estimates, which range from 300,000 to in excess of 500,000.

blind are a subset of the million who cannot read newspaper type, and (4) the 600,000 of the latter population who are not legally blind could benefit from a CCTV system, we may conclude that over 800,000 Americans could benefit from such a device.[4]

The value of our RANDSIGHT Ⓣ research is attested to by the hundreds of CCTV systems, based in large measure on the results of our research, that have been produced and sold to government agencies and private organizations and individuals.[5] These systems are helping partially sighted people of all ages. For example, they permit students to read the pages of a book, take notes, write reports, or do mathematics, allowing people of working age to compete for jobs that until recently have been closed to them because of their limited eyesight. (Such devices permit them to read plans, study diagrams, examine ledgers, make notes, and write reports.) CCTV systems are also enabling the elderly to read, write, and sew long after their vision has become so poor that they are unable to carry on these enjoyable activities with their unaided eyes or even with eyeglasses.

Many partially sighted people, who are unable to read or write even with the aid of eyeglasses, are very concerned with their inability to read personal mail, to examine bills, and to write checks without the help of a sighted person. Their inability to carry out such activities unassisted implies a loss of privacy and independence that irks them. Properly designed CCTV systems are enabling many of them to carry on these important day-to-day functions in complete privacy. Though this may not in itself justify the cost of a CCTV system, it nevertheless contributes a strong argument for placing such systems in the hands of many partially sighted people.

One of the primary reasons that a CCTV system proves so useful to the partially sighted is that it is an image enhancement device. This means that the signal received by the TV camera can be electronically manipulated in the camera, in the monitor, or in a "black box" placed between the camera and monitor to produce a magnified image on the monitor screen that is brighter and has greater contrast than the object being viewed by the TV camera. Electronic manipulation may also produce such effects as contrast reversal and an electronic window (for masking out unwanted images). Pure optical systems, consisting of lenses, prisms, mirrors, and ground-glass surfaces, do not have all of these useful capabilities. They present the viewer with a positive image that is not as bright as, and has less contrast than, the object being viewed.

Like pure optical devices, CCTV systems are capable of presenting the viewer with a magnified image. The degree of magnification needed by a particular viewer is a function of the status of his vision, his proximity to the monitor screen, and the original size of the object he is trying to resolve. With purely optical techniques, the

[4] One of the authors, S. M. Genensky, has no vision in one eye and 20/750 in the other. More than 60 percent of the legally blind have better visual acuity than he has. The fact that he has such poor visual acuity and is able to benefit so much from a CCTV system was one of the early indications to us that CCTV systems were potentially of value to many legally and nonlegally blind, partially sighted people. The experience of the partially sighted with our CCTV systems has supported this early conjecture.

[5] Neither The Rand Corporation nor the project staff has any financial interest in any company that manufactures, distributes, or sells CCTV systems for the partially sighted. Rand makes the results of its research freely available to any person or organization interested in helping the visually impaired.

same effective magnification is basically required but, besides the loss of contrast and brightness previously mentioned, the depth of field and the field of view may be less than that available with a good electro-optical system. In addition, properly designed CCTV systems allow the user to read or write while sitting comfortably before the monitor in a natural and relaxed position.

MAIN RESULTS OF THE RESEARCH

The principal results of our research over the past two years have been

1. To design and fabricate an improved CCTV system called RANDSIGHT II.
2. To ascertain that this and other black-and-white CCTV systems pose no x-radiation hazards.
3. To develop and test an important element for CCTV systems, called an X-Y Platform.
4. To test the performance of partially sighted persons with RANDSIGHT I (a predecessor instrument) equipped with an X-Y Platform.
5. To perform research toward designing a device called a Video Information Processor (VIP) capable of producing an electronic window, contrast enhancement, and contrast reversal.
6. To design a simple diagnostic test to be used for determining whether a partially sighted person could benefit from use of a CCTV system (the lightbox).
7. To establish some design criteria for CCTV systems and their components.

These results are summarized in the following paragraphs.

RANDSIGHT II

The closed circuit TV system that we call RANDSIGHT II is an experimental instrument that rests on a desk or table. It may be used with equal facility by both left- and right-handed viewers. Its down-pointing camera may be translated horizontally (e.g., to scan a line) by means of an electric motor drive, automatically or with foot- or hand-operated controls. Its camera may also be raised or lowered (for focusing) by means of a motorized drive with a hand-operated control, and the camera mount may be rotated manually about a vertical axis (to permit viewing an erect image no matter how the reading and writing materials are oriented). The instrument's two symmetrically placed monitors may be raised or lowered by means of a hand-controlled motorized drive, and pulled toward or pushed away from the viewer or rotated about one horizontal and two vertical axes. Hence, the monitors can be placed at any position and attitude that a viewer might desire. Each monitor is capable of presenting an image with normal or reversed contrast, and is also

equipped to introduce an electronic window. Contrast reversal is practically indispensable to partially sighted viewers who are photophobic, and it is preferred by many others, particularly those who are bothered by scattered light. An electronic window is particularly valuable to the partially sighted who are able to resolve print well enough to permit images of parts of several lines to be visible on the TV monitor at one time, but who are visually confused if the images of more than one or two lines are displayed.

RANDSIGHT II looks promising as a reading or writing device for the partially sighted. It also appears to be of value to the partially sighted as an aid for improving reading speed and comprehension. In addition, RANDSIGHT II (or a modification) may be of value as a reading aid for persons who have missing, inoperative, or partially operative limbs. Section II of this report describes RANDSIGHT II and how it operates; Sec. VI describes how contrast reversal and an electronic window were introduced into our monitors, and circuit details are given in App. C.

Test for X-Radiation

In order to test the system for possible x-radiation hazards, we engaged the firm of J. L. Shepherd and Associates of Glendale, California, to check the x-radiation output from three TV monitors, each operating at an acceleration voltage of 10 kv, and three others, each operating at an acceleration voltage of 19 kv. These measurements were made *directly against* the various faces of these black-and-white monitors, and in two instances their protective covers were removed and measurements were made of their interiors. It was found that external radiation levels arising from these monitors are *significantly less than 5 percent of background radiation.* On the basis of this finding, we believe that a viewer does not expose himself to any x-radiation hazard from black-and-white TV monitors operating at acceleration voltages as high as 19 kv, even if he were to bring his eyes up to the face of such a monitor for long periods of time. Section III contains more details regarding this exploration of a possible x-radiation hazard, and the test report by J. L. Shepherd is attached as App. A.

The X-Y Platform

The X-Y Platform is designed to enable the user of a CCTV system to easily move the reading or writing material in front of him in any desired position relative to a fixed TV camera. This procedure makes it unnecessary to move the camera or its lens system to achieve line or page scanning. This simple and inexpensive device has brought about a major change in the basic concept of a RANDSIGHT-type instrument and has profoundly affected the design of CCTV systems for the partially sighted. It has enabled manufacturers of such systems to design equipment selling for roughly half the price that prevailed before the construction and testing of the platform. Section IV provides a description of the X-Y Platform and its operation.

Tests of Performance by the Partially Sighted with RANDSIGHT I

As noted previously, an article by G. A. W. Boehm in the January 1971 issue of the *Reader's Digest* [9] attracted much attention to our RANDSIGHT research. We received hundreds of requests that the inquirer or his patient, client, relative, or friend be permitted to come to the Rand offices to try our RANDSIGHT equipment. We saw as many partially sighted people as we could accommodate. After some initial difficulties, we evolved a test procedure to handle these visitors. Naturally, we were delighted to have this opportunity to assist these partially sighted subjects and at the same time to gather valuable data regarding them and their performance with our RANDSIGHT equipment. As RANDSIGHT II was not yet completed at that time, we had our subjects work with RANDSIGHT I equipped with an X-Y Platform. Section V describes our test procedure and gives some generally encouraging results obtained from this informal testing program for 81 subjects. Informal as our tests were, they have provided empirical data indicative of the value of quality CCTV systems to the partially sighted. A description of the instrument used in these tests is given in App. B.

Electronic Image Enhancement

Near the end of the first year of the project, we were hoping that we would be able to design and perhaps build a third type of RANDSIGHT instrument, but this proved infeasible, primarily because it took longer to finish RANDSIGHT II than we had anticipated. However, we were able to perform research toward designing a "black box," which we call a Video Information Processor (VIP). This device, when placed between almost any TV camera and a TV monitor, allows the viewer to reverse the contrast in the image appearing on the monitor screen, to introduce an electronic window, to control the height and position of that window on the screen, and to enhance the contrast in the viewed image. The device has been used successfully with RANDSIGHT I. Additional information concerning VIP is given in Sec. VI and its circuit diagrams can be found in App. D.

The Lightbox Test

Another very promising result of our research is the development of a simple and inexpensive test designed to be administered to the partially sighted to determine whether they could benefit from use of a CCTV system in reading printed or handwritten material. The test, which can be administered quickly and simply by an ophthalmologist, optometrist, or other qualified person, consists essentially in having the patient sit before a lightbox and view positive and negative transparencies that display typewritten material magnified linearly 1, 2, 4, 8, and 16 times, noting what type sizes he can read and perhaps how well he can read them. A detailed description of this test is given in Sec. VII.

Design Criteria for CCTV Systems for the Partially Sighted

We have frequently been asked to state the criteria that we believe must be met if a closed circuit TV system for reading or writing is to be of value to the partially sighted. This is not easy to do, mainly because advances in electro-optical methods, as well as innovations in mechanical and electro-optical technology, make it necessary to alter criteria from time to time. With this reservation in mind, we assembled the criteria listed in Sec. VIII.

Other Research in the Area

The closing section of this report (Sec. IX) discusses some of the research on closed circuit TV systems for the partially sighted that has been conducted elsewhere and at Rand before the start of the work covered in this report.

PLANS FOR FUTURE RESEARCH

Rand research sponsored by the Social and Rehabilitation Service to date has led to the development of electro-optical instruments that permit the partially sighted to carry out *one* operation at a time. Reading or writing are examples of such activities.

Proposed future research has as its objectives

1. A general survey of opportunities for developing electro-optical devices to aid the partially sighted in obtaining education and employment, and in performing certain other activities that are of importance to them but that are currently beyond their capability or can be handled by them only with excessive expenditures of time and energy. Examples of such activities—which we call information transfer problems—include the following:[6]
   a. Reading printed or handwritten materials and taking rapid notes on what has been read with a pen or pencil.
   b. Typing from a handwritten or printed manuscript, and, if desired, viewing both the manuscript and a portion of the typewriter carriage at the same time.
   c. Viewing a chalkboard, bulletin board, or demonstration table and taking notes on or drawing sketches of what is seen.
   d. Entering into visual communication with teachers, colleagues, and friends for the purpose of more effectively receiving, discussing, or conveying handwritten and printed data and other sources of information with a large visual component.

[6] The term *information transfer* will be defined to mean the act of receiving information in one or more forms and, based on that information, generating the same or related information in one or more other forms, or carrying out other activities suggested or prescribed by the received information.

Examples of information transfer problems that, while interesting, are perhaps more restricted in scope than the above, are the following:

e. Operating an ordinary computer console while viewing ordinary input/output material.
f. Playing a musical instrument while viewing a handwritten or printed musical score.
g. Reading material in a foreign language, using a dictionary to assist in its translation and writing out the translation with a pen or pencil.

2. Development and testing of several types of instruments. Leading examples of the types of devices to be developed are those that will allow the partially sighted to perform activities that require rapid shifting between two or more visual fields (a process we shall call *visual information transfer*).
3. Development of a body of bioengineering data to facilitate the design of electro-optical prosthetic devices.
4. In addition, two specific issues should be addressed that we were unable to include in the current research program. First, the functional problems of the partially sighted should be structured in a way that suggests feasible types of prosthetic instruments for alleviating these problems. Second, the relationships between different kinds of visual impairment and the design parameters of electro-optical instruments that can best compensate for these impairments should be investigated.

II. RANDSIGHT II

The closed circuit TV system designed as part of our SRS/Rand-sponsored research program is called RANDSIGHT II. "RANDSIGHT" is the name we have chosen for the electro-optical instruments we design and fabricate for use by the partially sighted. The designation "II" refers to the fact that the prototype designed and fabricated as part of this project is the second type of electro-optical instrument we have built that we believed was worthy of a special designation. RANDSIGHT I was designed and built by the Rand staff solely with Rand support prior to the start of our SRS grant, and an evolved configuration of the original instrument is still in daily use by Genensky.

Although RANDSIGHT II is primarily a reading or writing instrument, it may be used to carry on other operations that require precise eye-hand coordination. It has features that no other CCTV systems possess and that are believed to be potentially of value to the partially sighted. One of these features is a vertically mounted, down-pointing camera that can be translated horizontally in any preselected vertical plane, which passes through the optical axis of the camera, by means of an electric motor drive with automatic, foot- or hand-operated controls. In the automatic mode, the control unit causes the camera mount to move automatically at a selected rate in one direction and at another selected rate in the opposite direction. Among the other features are the monitor mounts, which have two translational and three rotational degrees of freedom that permit each monitor to be placed in any position or attitude the viewer may desire.

The planning of RANDSIGHT II was strongly influenced by our dissatisfaction with some of the shortcomings of the then existing RANDSIGHT I, and by our determination to correct those deficiencies. Among that instrument's more important shortcomings were the following: It had been built to be used by a right-handed person and hence left-handed persons found it awkward to operate. Its line scanning was carried out through a hand-operated servomechanism that caused its down-pointing camera to rotate about a horizontal axis passing roughly through the center of mass of the camera. The major disadvantage of such a driving mechanism is that as the camera is rotated, the distance between the camera and the handwritten or printed copy also varies. Thus, it is difficult to keep the copy in focus especially

when high linear magnification is demanded and the camera is equipped with a short focal length lens with its aperture wide open.

In RANDSIGHT II, the right-handed bias was eliminated by providing two monitor mounts symmetrically placed on either side of the camera mount and having considerable and equal flexibility with respect to monitor location and attitude, and by mounting the camera vertically and pointing downward in a housing that can be rotated about the optical axis of the camera.

Several methods were proposed for overcoming the defocusing problem. Some of them involved using prisms or mirrors and supplying a mechanism that would change the lens-to-prism or lens-to-mirror distance to compensate for changes in the distance from camera to copy. These methods were rejected on the grounds that they were too complicated and unwieldy. The decision was finally made to drive the camera mount along a horizontal ball-bearing track by means of an electric motor, which controls the motion of the mount in both direction and speed. This decision not only solved the problem of maintaining a constant distance between the camera and the copy, but it also opened up the possibility of trying various options for controlling the horizontal motion of the camera. However, we encountered some difficult mechanical design problems, for example, that of moving a relatively massive camera mount very rapidly and smoothly over a horizontal distance of several inches.

MECHANICAL DESIGN

The detailed mechanical design of RANDSIGHT II began with the mechanism for driving the camera. This was the most complicated and difficult mechanism to design because it involved providing a means to convey, electromechanically, the camera horizontally and vertically, to rotate it mechanically about its optical axis, and to do this in such a way that the camera mount remained compact and provided sufficient rigidity. While this mechanism was being built and when it was being checked out as an operating unit, design was in progress on less complicated items, such as monitor mounts and the instrument's basic frame.

The vertical and horizontal motions of the camera are produced by electric motors through rack and pinion gear systems (see Fig. 1). The mechanism providing vertical travel is relatively simple, as it is designed to raise or lower the camera at one and only one constant rate. On the other hand, the mechanism for translating the camera horizontally is much more complex, as it permits the camera to move to the right and to the left at variable speeds that are independent of each other and to make a rapid return to the left end of its path from any other point in its path. Some of these motions involve large inertial loadings, and heavy duty motors must be used. Initially, we expected to design and build appropriate motor control circuits in our own facilities; we then found a local manufacturer of motor controls (Minarc Electric Company, Los Angeles, California) who was able to provide us with a control

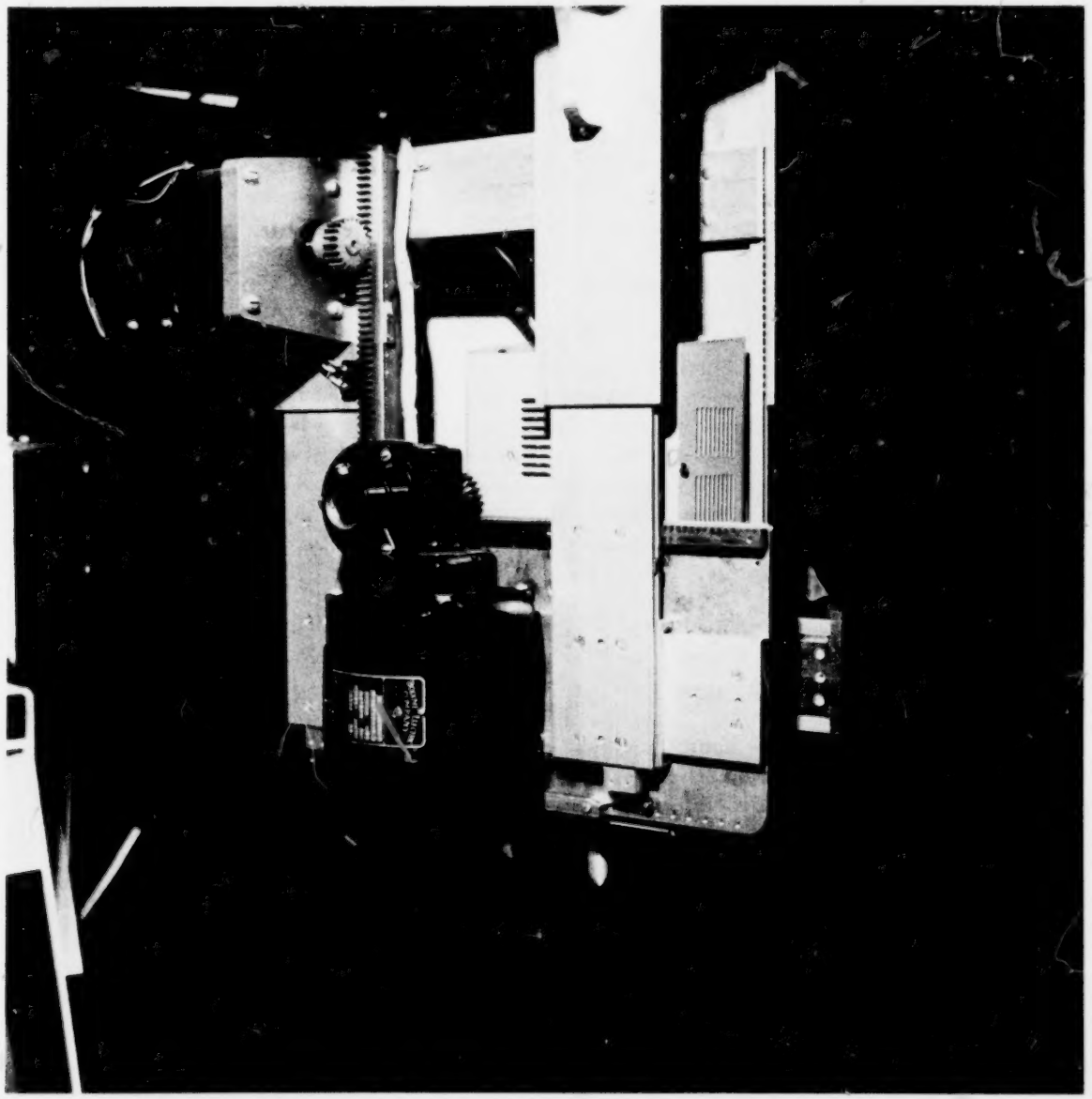

Fig. 1—Side view of RANDSIGHT II's camera mount showing motors and some of the rack and pinion gear systems that provide vertical and horizontal motions

unit that satisfied most of our needs.[1] The unit was incorporated into our instrument design with the expectation that we would later make modifications in its circuitry to improve its operation according to our needs.

THE INSTRUMENT

RANDSIGHT II is a free-standing device; that is, it can be placed on a desk or table. Its frame consists of tubular members, all of which are of square cross-section (1½ in. on an edge). It rests on two parallel tubular members (1)[2] that run from the front to the back of the instrument and are 24 in. long and 45 in. apart. On either side of the instrument frame, vertical members (2) and (3), located at the rear of the base members and 8½ in. forward of that end of the base members, rise 30 in. to provide support to the canopy (4), from which the TV camera and TV monitor supports (5) and (6), respectively, are suspended. Additional frame rigidity is provided by

1. A horizontal tubular member (7) that is 45 in. long, that joins the vertical members (2), and that is 14¾ in. above the base of the frame.
2. Two inclined members (8) that connect the far ends of the base and vertical

LIST OF PARTS OF RANDSIGHT II SINGLED OUT IN FIGS. 2, 3a, 3b, 4a, 4b, AND 4c

1. Base members
2. Corner vertical members
3. Side vertical members
4. Canopy
5. TV camera support or mount
6. TV monitor support or mount
7. Horizontal rear member
8. Inclined rear member
9. Rear vertical member
10. Canopy frame
11. Canopy wooden member
12. Canopy center opening
13. Canopy flank opening
14. Supporting table
15. Illumination housing
16. TV monitor
17. TV camera
18. Zoom lens
19. Toggle switch housing
20. The unit or control unit
21. Two-position foot pedal
22. Rapid return foot pedal
23. One-position foot pedal

[1] Throughout the rest of this section, "control unit" and "unit" are used interchangeably.

[2] Throughout this section of the report, names of various parts of RANDSIGHT II will be followed by numbers enclosed in parentheses the first time a name is mentioned in a paragraph (see the list on this page). The numbers in parentheses also appear in conjunction with Figs. 2, 3a, 3b, 4a, 4b, and 4c. There they indicate where the part being discussed is located in the overall instrument design.

members (1) and (2) with the center of the horizontal member (7).

3. A vertical member (9) that rises 15 in. from the center of the horizontal member to meet the center of the rear edge of the canopy.

The canopy (4) is roughly rectangular and consists of a tubular frame (10), about 48 in. long and 23 in. deep, topped by a rectangular board (11) that is about 47 in. long, 23 in. deep, and ¾ in. thick. Three circular holes with lips have been cut in the board, and the TV camera mount is suspended from the lip around the edge of the center hole (12). The TV monitor mounts are suspended from the lips around the holes (13) to the right and left of the center hole.

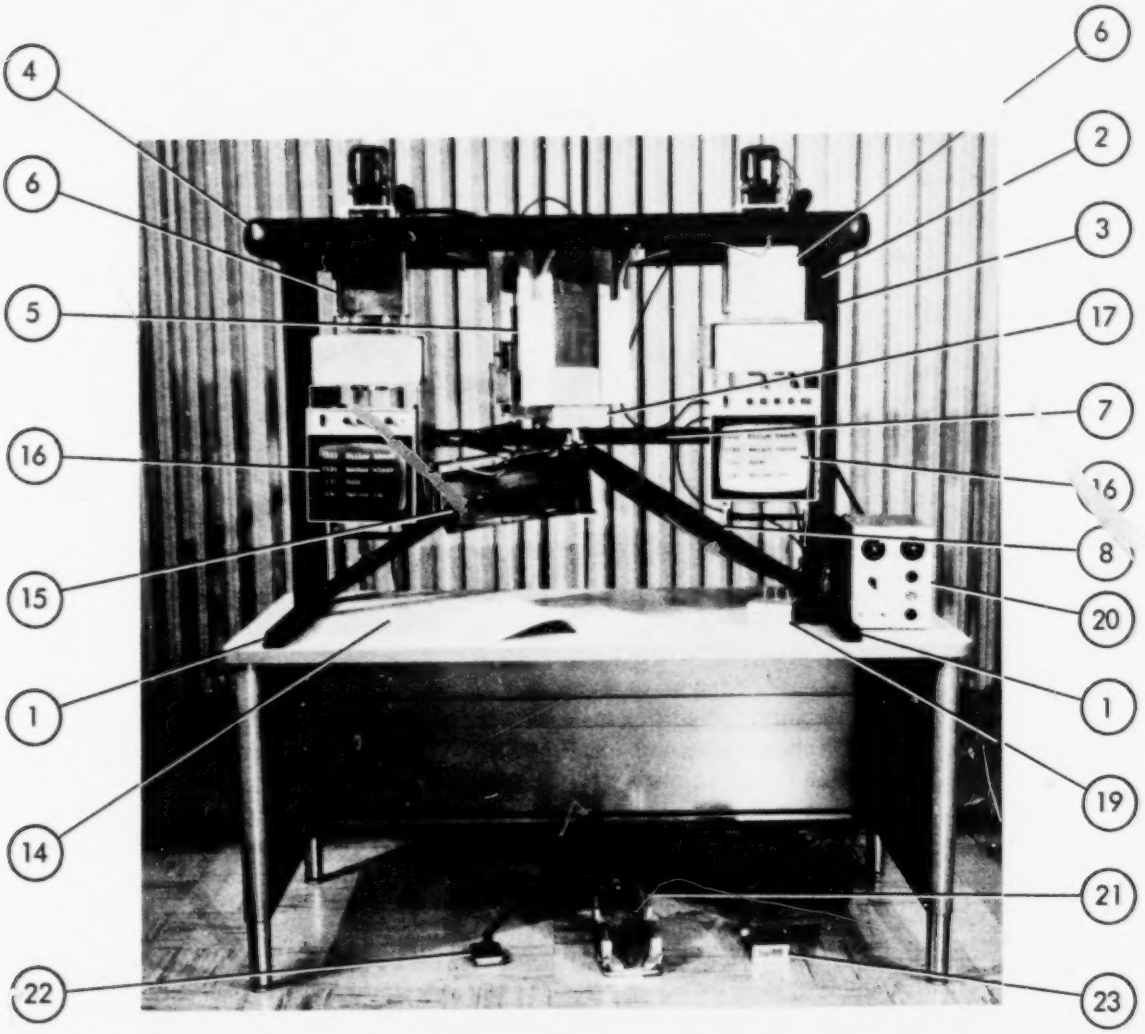

Fig. 2—Front view of RANDSIGHT II

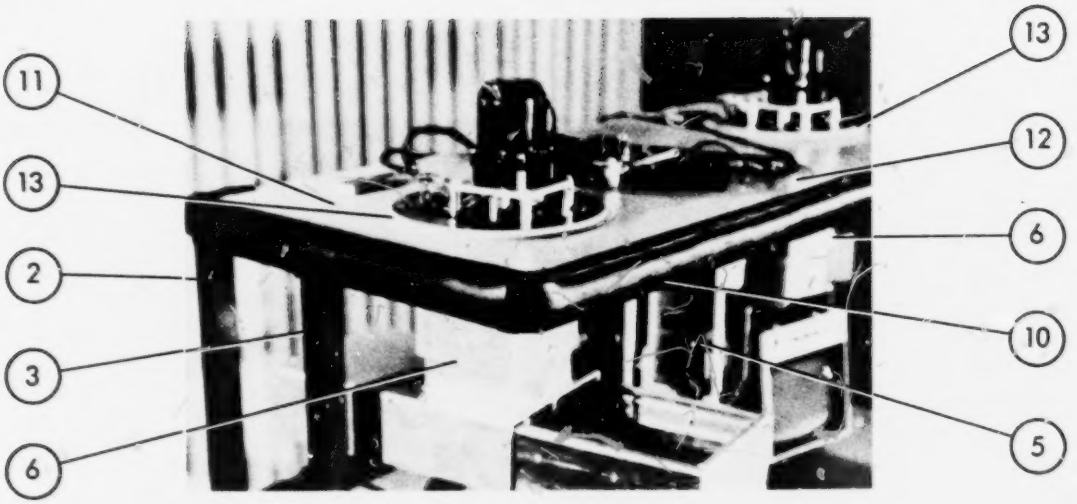

Fig. 3a—View of the top of RANDSIGHT II

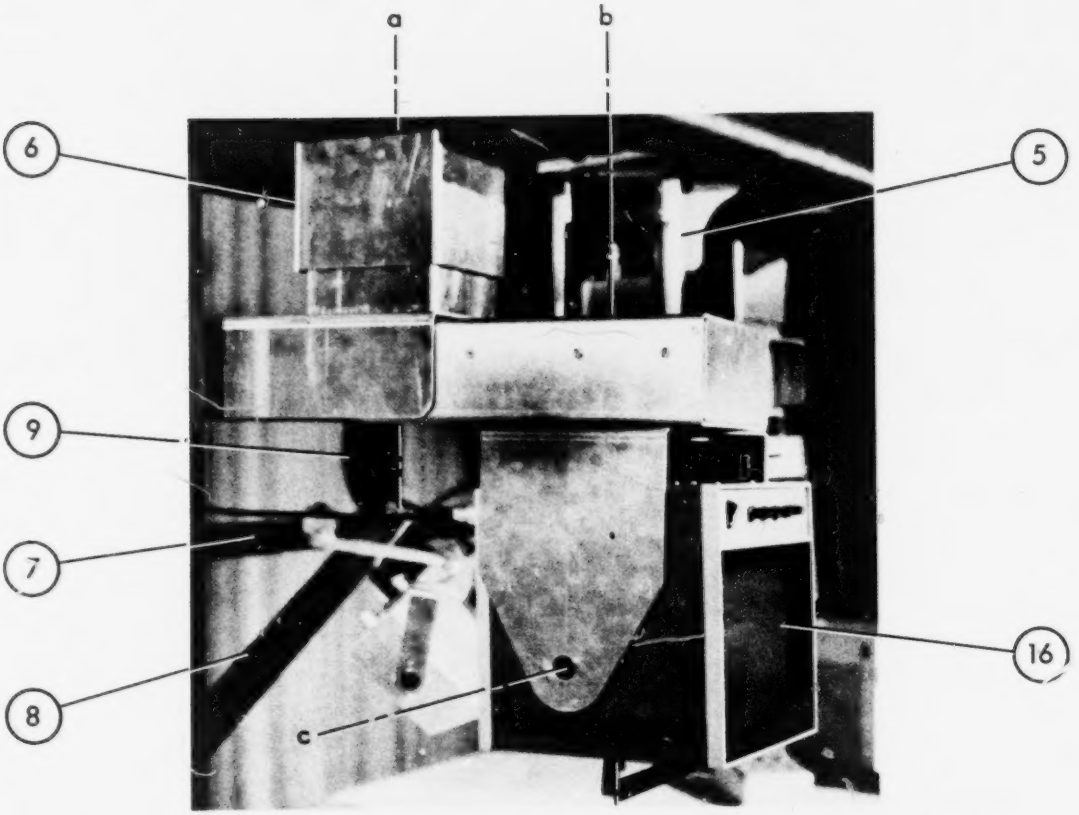

Fig. 3b—Monitor and monitor mount of RANDSIGHT II

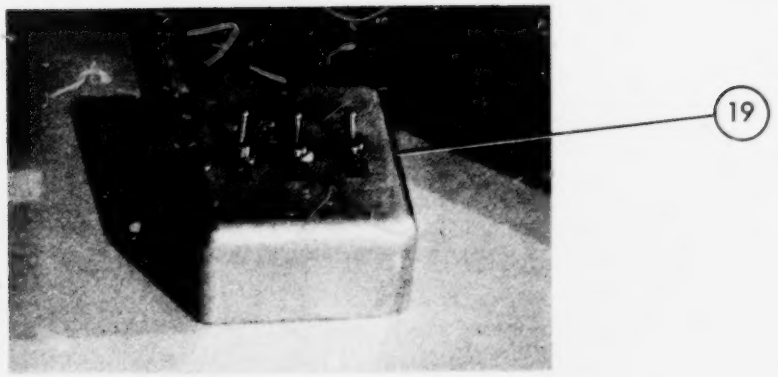

Fig. 4a—Box containing switches that control the vertical motion of the camera and monitors

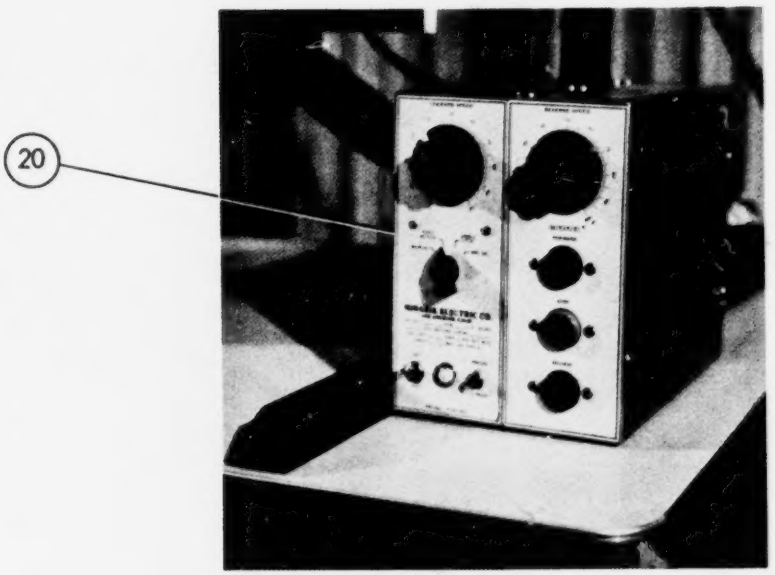

Fig. 4b—The control unit

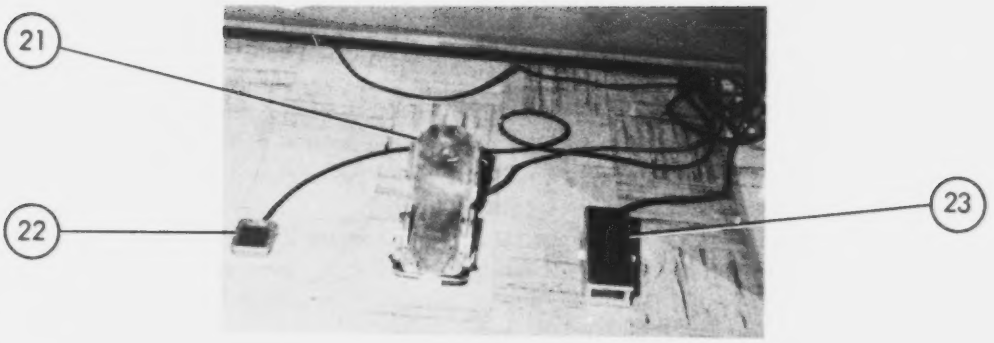

Fig. 4c—Foot pedals that control the horizontal motion of the camera

Illumination of the reading or writing material on the supporting surface (14) is provided by two 8-w fluorescent tubes located in an aluminum housing (15) of our own design. The aluminum housing is attached to the upper surface of the horizontal member (7) by means of a flat-jointed aluminum arm. The housing can be easily and conveniently positioned at any angle behind the TV camera mount (5) by means of the jointed arm, and it can be rotated about a horizontal axis approximately 10½ in. above the supporting surface. The illuminator provides an effective light level of 78 footcandles over the entire range of horizontal motion of the camera.

The TV monitor mounts (6) permit several manual adjustments in monitor positioning, namely,

1. Horizontal translation toward or away from the viewer through a distance of 13 in. (As currently configured, RANDSIGHT II is equipped with Shibaden Model MV-903 monitors (16), and these can be translated horizontally so that their screens are located somewhere between 5 in. in front of the near end of a horizontal support (1) and 8 in. behind that reference line.)
2. Rotation about two vertical axes (one passing through the mounting column and the other passing through the monitor itself).[3]
3. Rotation about a horizontal axis passing through the monitor and parallel to its front face.[4] All of these modes of rotation are large enough to meet the needs of any viewer. The monitor mounts also permit the monitors to be raised or lowered electromechanically through a distance of 5 in. As currently configured, this permits the lower surface of the monitors to be located anywhere between 6 and 11 in. above the supporting desk or table (14).

[3] These axes are indicated as broken lines a and b, respectively, in Fig. 3b.

[4] This axis is shown as broken line c in Fig. 3b.

Each monitor (16) is augmented with circuitry and controls that permit contrast reversal and an electronic window. Contrast reversal is the ability to reverse, electronically, the order of the gray scale, and the electronic window is the blanking out of everything on the monitor screen except a strip of a fixed but arbitrary height. The controls on the back of each monitor permit the viewer to select an image with either a normal or reversed gray scale, to introduce an electronic window, and to vary its height and position on the monitor screen.[5]

Figures 5a and 5b illustrate some of the freedom that is available in positioning a TV monitor (16). Figure 5a shows the monitor all the way back and at its highest position, while Fig. 5b shows it all the way forward, at its lowest position, and rotated about the horizontal and both vertical axes.

The camera mount (5) is also designed to allow considerable latitude in camera positioning. It permits the camera (17) (a GBC Model VR 622)

1. To be rotated manually through nearly any angle about the vertical axis passing through the center of hole (12).
2. To be raised or lowered vertically electromechanically through a distance of 8 in. (between about 4¼ and 12½ in. above the supporting table (14)).
3. To be translated horizontally through a distance of 7 in. with the current setting of the limit switches.

The vertical translation of the camera (17) and each of the two monitors (16) are controlled by their own toggle switch, which is pulled toward the viewer to make it descend and pushed away from him to make it rise. All three switches have been placed in a conveniently located housing (19) (see Fig. 4a).

OPERATIONAL CONTROL

One method of governing the camera's horizontal motion that had appeared to be attractive from the beginning of our work on RANDSIGHT II was through a foot control. Such a control mechanism had the important advantage of leaving both of the viewer's hands free for manipulating reading and writing materials. The control unit (20) came equipped with a foot pedal, but it did not prove satisfactory, appearing to have been designed for use by an operator who was standing rather than seated. Further, it was capable of controlling only the speed at which the camera (17) moved horizontally. The direction in which the camera moved and the ability to stop its motion were controlled by push buttons mounted on the front of the control unit.[6]

Soon after RANDSIGHT II became quasi-operational, we decided to design our own foot-operated control for governing the camera's horizontal motion. This foot-operated control, which we shall call the "two-position foot pedal" (21), governs not

[5] Contrast reversal and the electronic window are discussed in greater detail in Sec. VI.

[6] The foot pedal referred to here is identical with the one-position foot pedal referred to in the description of mode C later in this section.

Fig. 5a—View of TV monitor all the way back and at its highest position

only the speed with which the camera (17) translates horizontally, but also the direction in which it moves, as well as when it is to start or stop these motions. This control completely bypasses the knob and push-button controls mounted on the front face of the control unit (20). To permit operation of the control unit with the two-position foot pedal, modifications had to be made in the circuitry of the unit. These modifications also permitted operation of the unit with other external controls. The unit's operation in various control modes is described below.

Mode A: The camera's direction and speed can be controlled by means of the two-position foot pedal (21). When the upper portion of the pedal is rotated to the left and depressed, the camera (17) moves to the left, and when it is rotated to the right and again depressed, the camera moves to the right. The rate at which the camera moves depends on how far the pedal is depressed. Mechanical stops and limit switches are provided at each end of the camera's path to prevent its mount (5) from colliding with the monitor mounts (6), instrument frame, or any other obstructions. If the camera is at the right (left) end of its path and the two-position foot pedal is rotated to the right (left) and depressed, the camera will not move because of the action of the limit switches. This permits the viewer to easily predict and control camera location. Although this foot-pedal control system is very versatile, it is

Fig. 5b—View of TV monitor all the way forward, at its lowest position, and rotated about a horizontal and two vertical axes

complex and somewhat difficult to operate. However, with a few minutes of instruction and an hour or two of practice, the viewer usually finds that he can operate it smoothly and easily.

All the modes of causing the camera (17) to translate horizontally are governed by the unit (20). The mode just described is engaged when the cable connected to the two-position foot pedal (21) is secured to the upper cable receptacle on the back of the unit and when the switch on the back of the unit is set on "MANUAL." In this mode all the knobs, switches, and buttons on the front of the unit are disengaged, with one exception—the "STOP" button. If this button is depressed, the two-position foot pedal will not function.

Mode B: The camera mount (5) and hence the camera (17) may be set to translate automatically back and forth horizontally by

1. Disengaging from the back of the unit (20) the cable that runs from the two-position foot pedal (21) and replacing it by the free end of the cable that is already connected to the lower cable receptacle on the back of the unit.
2. Turning the switch on the left side of the front of the unit to "AUTO-RECYCLE."

3. Selecting the left-to-right speed by adjusting the knob marked "FORWARD SPEED."
4. Choosing the right-to-left speed by adjusting the knob marked "REVERSE SPEED" (see Fig. 4b).

While in Mode B, and while the camera is moving toward the right, it can be brought to a stop *and* automatically returned to the left end of its path by depressing the "STOP" button on the unit or by momentarily depressing the rapid return foot pedal (22).

Mode C: The camera (17) may be translated horizontally under control of the one-position foot pedal (23) with the wiring connected and the knobs and switches on the unit (20) set as in mode B with one exception—the switch on the back of the unit is set on "FOOT" rather than on "MANUAL." Here, the forward motion of the camera can be stopped *and* the direction of camera motion changed by pressing the "STOP" button on the unit or by depressing the rapid return pedal (22).

READING [7]

To read with RANDSIGHT II, the viewer places reading matter on the supporting desk or table at whatever angle is convenient and comfortable for him and rotates the camera mount until the image of the reading matter on the monitor screen shows the lines of print to be horizontal.[8] He may find it necessary to change the distance between the zoom lens and the reading material to bring the latter into focus. To do this he would be well advised to rotate the sleeve on the zoom lens to the position where it produces its maximum magnification, rotate the sleeve that controls the lens focus to its uppermost position, and then manipulate the middle key on the three-key control box until the image of the reading material is in focus.[9]

[7] It is important to note that RANDSIGHT II may also be used in conjunction with an X-Y Platform for reading and writing. Section IV of this report describes our X-Y Platform and how it is used to carry out those operations.

[8] For most viewers, the angle through which they rotate their reading or writing material, relative to the orientation of the supporting desk or table, will not vary appreciably from one piece of reading matter to another, or from one piece of writing material to another. Therefore, they will have a tendency not to change the angle of rotation of the camera support once they have set it initially. If, however, the instrument is used by several viewers, some of them may wish to change the angle of rotation before starting to read or write with the device.

It is also possible that a viewer may prefer his reading material to be inclined at one angle and his writing material at another, and this would lead him to rotate the camera mount before carrying out each of these operations. Most viewers, however, rotate the camera mount to suit their writing habits and do both their reading and writing without further altering the camera's angle of rotation. However, those who prefer writing material rotated through an unusually large angle may prefer rotating their reading material through a smaller angle, because by doing so it may be easier for them to maneuver their material from line to line across the supporting desk or table while reading.

[9] This focusing procedure is particularly useful if it is carried out with respect to the minimum thickness of material expected to be encountered while reading. It permits the zoom lens to be brought into focus when viewing a greater thickness of material by merely rotating the focusing sleeve, if the thickness of the reading material does not exceed the focusing range of the zoom lens. For example, a 6-to-1 Canon zoom lens fitted with a plus 4 portrait lens, and with its iris wide open (at f:2), can be focused with its focusing sleeve over a range of about 1½ in.

The viewer may use either monitor. Right-handed viewers tend to prefer the left-hand monitor; the opposite is true of left-handed viewers. It is advisable for the viewer to make himself comfortable in his chair and to place it in such a position that he is easily able to do such things as manipulate the reading material and bring a TV monitor into position for viewing. As stated earlier, RANDSIGHT II permits each of its monitors to be moved up and down and toward or away from the viewer and to be rotated about one horizontal and two vertical axes. All of these degrees of freedom in each monitor's motion permit either monitor to be located and oriented in a way that is suitable to the individual.

In mode A the viewer places his right foot on the two-position foot pedal, rotates its upper face to the left, depresses the pedal until the camera reaches the left end of its path, and adjusts the position of the reading matter until the image of its left margin is near (or at) the left end of the monitor screen, so that the first line to be read is at the desired height on the screen. The viewer then rotates the upper portion of the foot pedal to the right, depresses the pedal until it causes the print or handwriting to advance at a rate compatible with his ability to read, and commences to read. When he reaches the end of the line, he releases pressure on the pedal, which causes the camera to come to a halt; rotates the upper portion of the foot pedal to the left; depresses the pedal all the way or nearly all the way to cause the camera to move rapidly to the left; and releases the pressure on the pedal when the camera reaches the left end of its path where it will automatically stop. He then pushes the reading matter along and toward the rear of the supporting desk or table until the next line of print or handwriting has moved into the position on the monitor screen previously occupied by the line that was just read. This process is repeated line by line until the viewer has reached the bottom of the page. The steps described above are then repeated for each successive page.

Mode A permits the viewer to retrace all or part of a line by merely releasing pressure on the two-position foot pedal, rotating its upper portion to the left, and depressing the pedal until the material he wishes to see a second time comes into view. Figure 6 shows the viewer reading in mode A.

In mode B, the camera can be brought to the left end of its path by, for example, turning the small switch on the left side of the front face of the unit to "SINGLE CYCLE" and depressing the "START" button. Care must be taken to be sure that the "FORWARD SPEED" and "REVERSE SPEED" knobs are not set on zero, for if they are, the camera will not recycle.

When the camera is at its left margin, the reading material can be located so that the image of its left margin and that of its first line are conveniently located on the monitor screen. If the switch on the left side of the front of the unit is then turned to "AUTO-RECYCLE" and the "START" button is depressed, the camera will move automatically from left to right and from right to left at speeds that are governed by the "FORWARD SPEED" and "REVERSE SPEED" knobs. Since English and other languages are written and printed from left to right, no useful information is conveyed to the viewer while the camera is moving to the left, and it is advisable to turn the "REVERSE SPEED" knob to its maximum setting. The preferred setting of the "FORWARD SPEED" knob is determined by an iterative

Fig. 6—RANDSIGHT II being used for reading in mode A

process involving adjusting the knob and, for example, running over the first line one wishes to read until the speed with which the camera moves to the right is compatible with the viewer's reading comfort. Once this is done, and while the camera is nearing the end of its traverse toward the right or returning to the left end of its path, the viewer moves the reading matter toward the rear of the supporting desk or table so that the next line moves into the position on the monitor screen occupied by the previous line. The viewer then reads that line while the camera makes its way to the right end of its path. Subsequent lines are brought into position on the monitor screen as just described.

In mode B the viewer may interrupt the camera's motion to the right and send it rapidly and directly back to the left end of its path by merely depressing the rapid return pedal. This is particularly helpful when the remainder of a line contains no additional information.

Occasionally it may be useful to adjust the "FORWARD SPEED" knob so that the print or handwriting progresses across the screen slightly more rapidly than the viewer would initially consider comfortable or desirable. If this were done, it might be possible for the viewer to increase his reading speed. However, in some cases, it is advisable for the viewer to select a forward speed that does not tend to overly challenge or threaten him. In any event, when *first* working with RANDSIGHT II, it is not advisable to try to improve one's overall reading speed.

Reading in mode C is carried out much as it is in mode A with some important exceptions. In mode C the camera's left-to-right and right-to-left motions are controlled by the one-position foot pedal. Since the one-position foot pedal is only capable of regulating the rate at which the camera cycles back and forth between the end points of its path, it is not capable at any arbitrary time of causing the camera to retrace a portion of its path. However, in mode C the rapid return pedal is semiautomatic. By depressing that pedal while the one-position foot pedal is being depressed, it is possible to start the camera back to the left end of its path.

The one-position foot pedal tends to cause the camera to leap to the right (left) when it reaches the left (right) end of its path if care is not taken to release pressure on the pedal just before this occurs. This is especially annoying when it occurs at the left end of the camera's path.

WRITING

To write with RANDSIGHT II, the viewer places his writing material on the supporting desk or table at whatever angle he finds convenient and comfortable,[10] and rotates the camera mount until the image of the writing material on the

[10] We have found that most people who have tried to use our RANDSIGHT equipment prefer to write on lined paper, because the lines allow them to judge easily when the image of the paper is erect and when their writing is falling away from the rulings. Genensky, who has used this equipment on a day-to-day basis, has found that it is not too difficult to write on nonruled paper and still generate handwriting that is straight and evenly spaced, wordwise and linewise.

monitor is erect. As in the case of reading, it may be necessary to change the distance between the zoom lens and the writing material to bring the image into focus. To do this the viewer is advised to follow the steps described in the previous section.

The viewer is free to work with either monitor. As was pointed out, right-handed persons prefer to use the monitor on the left and left-handed persons, the one on the right. The viewer should make himself comfortable in a chair before the preferred monitor, and should position the chair so that he can easily manipulate the writing equipment and bring the TV monitor into a position and orientation that is convenient for viewing.

To write with RANDSIGHT II, the viewer uses either mode A or C. Mode B is not very satisfactory for writing, because unless the viewer knows exactly what he wants to write at every moment, the camera will tend to either lead or lag relative to the rate at which the viewer is able to commit his thoughts and ideas to paper.

In either mode A or C, the viewer holds down the writing material with one hand and grips his pen or pencil with the other. The nonwriting hand usually holds the paper in place by means of the thumb and the first two or three fingers. Either one or both hands may be used to push the writing material along and toward the rear of the supporting desk or table to cause the image of that material to advance from line to line.

In mode A, the viewer, using the two-position foot pedal, first causes the camera to move to the left end of its path and then locates his writing material so that the image of its left margin and the first line on which he wishes to write are conveniently located on the monitor screen. He then rotates the upper portion of the foot pedal to the right, and as he begins to write, he depresses the pedal in such a way as to keep the writing end of his pen or pencil in view on the monitor screen, so that the image of the pen or pencil ranges over a very small area of the display surface. Genensky has found that this can be accomplished by bringing the image of the writing end of his pen or pencil into view and within a selected small area of the screen, writing a few symbols, depressing the foot pedal so as to shift the camera enough to bring the image of the writing end of the pen or pencil to where it was prior to writing those symbols, releasing pressure on the pedal, writing a few more symbols, and repeating the process until the right margin of the writing material is attained. When this occurs, the viewer rotates the upper portion of the foot pedal to the left, depresses it so as to cause the camera to traverse rapidly to the left end of its path, and then, using one or both hands, pushes the writing material toward the rear of the supporting table or desk to move the line on which he now wishes to write into the position on the monitor screen previously occupied by the line on which he just finished writing. The process described above is continued until the viewer reaches the bottom of the page and is repeated for each successive page.

In mode A the viewer can retrace a portion of a line *at any time* using the simple technique described in the previous section. As mentioned earlier, mode C can also be used for writing though, compared with writing in mode A, mode C is not as satisfactory for the same reasons as those given with regard to reading in mode C.

SUMMARY REMARKS

RANDSIGHT II is an experimental CCTV system that incorporates features not found in any other CCTV system prior to its construction. These include (1) a vertically mounted, down-pointing camera that can be translated horizontally in any vertical plane passing through the optical axis of the camera by means of an electric motor drive with automatic or foot- or hand-operated controls, and (2) monitor mounts that have two translational and three rotational degrees of freedom that allow each monitor to be placed in any desired position or attitude. Each monitor is equipped with circuitry and controls that are capable of producing contrast reversal and an electronic window.

Although RANDSIGHT II was completed too late in the project to have undergone extensive testing, the little testing that did occur indicates that it is easy and comfortable to use in mode A for both reading and writing and in mode B for reading. In mode B it offers interesting possibilities as a method of assisting the partially sighted (as well as the normally sighted) to improve their reading speed and comprehension. Several teachers of the partially sighted who have seen RANDSIGHT II in use and have tried it themselves have expressed enthusiasm concerning its potential value in resource rooms.

As currently configured, or perhaps with some modifications, modes A and B may also be of value to those who have missing, inoperative, or partially operative limbs. For these people, the ability to make the camera move from line to line, as well as to scan a line using automatic or foot-operated controls, may be desirable and deserves to be investigated. A modification of mode C to provide an automatic rapid return capability might also be of interest.

III. X-RADIATION

To determine the x-radiation emitted by the monitors used in our RANDSIGHT research, as well as that emitted by a set of larger monitors used in other Rand projects, we contacted and evaluated the responses of a half-dozen companies engaged in the development, manufacture, and distribution of radiation-measuring instruments. It was decided to hire J. L. Shepherd and Associates, Glendale, California, not only because their equipment was suitably designed but also because they were willing to send equipment and personnel to Rand. In November 1970, President Shepherd came to our offices and made the necessary measurements on six TV monitors. The make, alphanumeric designation, serial number, and acceleration voltage of the six monitors examined are given in Table 1.

Measurements were made with a "J. L. Shepherd and Associates USM-1A rate meter" equipped with an SP-12 GM probe, which had a 1-sq-in. mica window (density 1.4 mg/cm^2). The efficiency of the SP-12 probe is 2.5 percent as measured against a ^{55}Fe standard source that emits 5.9 kev photons. This source is manufactured by Isotope Products Laboratories, and its calibration is traceable to standard sources at the National Bureau of Standards. All of the monitors examined had maximum count rates (above background) of less than 80 counts per minute. Furthermore, the actual count rate was below the sensitivity of the equipment used in the survey over most of the monitors' faces and within their interiors.

With respect to the detection equipment used in making these radiation measurements, 82 counts per minute represents a radiation field of 0.17 microroentgens per hour for 10-kev x-rays and 0.32 microroentgens per hour for 19-kev x-rays.

All the monitors surveyed were scanned on all accessible faces,[1] and all scans were made directly against the surfaces under examination. One of the Shibaden monitors was scanned with its case removed, and another was scanned with and without its transparent plastic face plate. One Conrac monitor was also scanned without its protective housing.

Mr. Shepherd concluded, and we concur, that for the 10-kv Shibaden and 19-kv Conrac monitors tested, external radiation levels from the monitors are *significantly*

[1] Six faces in the case of the 9-in. Shibadens and five in the case of the massive consoles that contained the 19-in. Conracs.

Table 1

INSTRUMENTS MEASURED FOR X-RADIATION

Instrument Identification	Acceleration Voltage (kv)
Shibaden VM-903 LA 10802, Serial No. 090906	10
Shibaden VM-903 RA 02039, Serial No. 030562	10
Shibaden VM-903 RA 02039, Serial No. 030732	10
Conrac CQF-9 Serial No. 171362	19
Conrac CQF-21/875-60 Serial No. 184778	19
Conrac CQE-17-875/945SP Serial No. 99217	19

less than 5 percent of background radiation.[2] We believe that on the basis of these tests and on calculations that we reported in 1969 [4], it is safe to conclude that a person does not expose himself to any radiation hazard from black-and-white TV monitors and receivers operating at 19 kv or less even if he were to bring his eyes up to the face plate of such monitors for indefinitely long periods of time.

A letter from J. L. Shepherd and Associates to The Rand Corporation dated December 2, 1970, is reproduced in App. A to this report. This letter contains the findings that they made during their visit to Rand in November 1970.

[2] The total background radiation received per annum by human beings at sea level is 80 millirems (30 millirems from cosmic rays and 50 millirems from terrestrial sources). For x-radiation, 1 rem is approximately equal to 1 rad, and if we assume that for the human eye the absorbed x-radiation in rads is 0.9 times the exposure dose in air measured in roentgens, we may conclude that the exposure dose in air at sea level from background radiation is 89 milliroentgens per year or about 10 microroentgens per hour.

IV. X-Y PLATFORM

The X-Y Platform, designed by R. W. Clewett and fabricated in the Rand model shop, is a hand-operated mechanical device that has profoundly affected the design of closed circuit TV systems for the partially sighted. It has enabled manufacturers of quality instruments to design equipment for roughly half the price prevailing prior to the design and evaluations of our platform.[1] Most important is that the use of an X-Y Platform simplifies instrument design without sacrificing instrument quality. It is now possible to maneuver, easily and rapidly, reading and writing materials below a fixed camera. This appears to be preferable to having the camera or its lens system move, through a hand-operated control, in order to achieve line or page scanning. This change in the basic concept of earlier RANDSIGHT-type instruments led to the cost reduction described above.

The discussion that follows is taken in large measure from Ref. 6. Additional details regarding our X-Y Platform and its operations are given in that reference.

DESCRIPTION OF THE X-Y PLATFORM

The X-Y Platforms currently in use with RANDSIGHT I and occasionally with RANDSIGHT II may be thought of as consisting of four relatively thin layers. The bottom layer is made up of a 12 by 14-in. rectangular aluminum base plate (1),[2] 3/16 in. thick, to which is cemented a 1/8-in. rubber pad (2) of the same dimensions. The rubber pad prevents the X-Y Platform from slipping on a smooth desk or table and reduces the possibility of scratching or otherwise damaging the supporting surface. The second layer consists of a pair of Jonathan 145 QD "Thinline" aluminum drawer slides.[3] The inner members (3) of these slides are held in place by screws that attach

[1] See footnote 5 on page 2.

[2] Throughout the remainder of this section, names of various parts of the X-Y Platform will be followed by numbers enclosed in parentheses the first time a name is mentioned in a paragraph (see the list on p. 28). The numbers in parentheses also appear in conjunction with Figs. 7, 8, and 9. There they indicate where the part being discussed is located in the overall design of the platform.

[3] Jonathan Manufacturing Company, Fullerton, California.

both the members and the stop blocks (4) to the aluminum base plate. Each of the members of this pair of slides is 12 in. long, and the stop blocks are positioned to permit the outer members (5) to move through a distance of 8¾ in. This pair of drawer slides governs the left-to-right and right-to-left motions of the X-Y Platform's working surface (6). The third layer consists of another pair of drawer slides placed at right angles to the slides in the second layer. The inner members (7) of these slides are held in place by screws that pass through their stop blocks (8) and terminate in the outer members of the slides in the second layer of the platform. Each of the slides in the third layer is 14 in. long, and its stop blocks allow its outer member (9) to traverse a distance of 11¾ in. These slides control the line-to-line motion of the X-Y Platform's working surface. The fourth and topmost layer of the platform is the working surface, consisting of a 12 by 14-in. rectangular sheet of masonite, ⅛ in. thick, topped by a 3/64-in. sheet of steel of the same dimensions.[4] This topmost layer is held in place by screws that fasten it to the outer members of the slides in the X-Y Platform's third layer.

LIST OF PARTS OF THE X-Y PLATFORM SHOWN IN FIGS. 7, 8, AND 9

1. Base plate
2. Rubber pad
3. Inner member of drawer slide (second layer)
4. Stop block (second layer)
5. Outer member of drawer slide (second layer)
6. Working surface
7. Inner members of drawer slide (third layer)
8. Stop block (third layer)
9. Outer member of drawer slide (third layer)
10. Adjusting rod
11. Pillow block
12. Anchor block
13. Knob
14. Spring bar
15. Spring
16. Lever bar
17. Pivot stud
18. Brake shoe
19. Brake rail
20. Steel balls

Our experience has shown that it is advisable to provide a means of imposing a variable source of frictional loading on the drawer slides that govern the line-to-line motion of the X-Y Platform's working surface. When this is done, even if the TV camera is transmitting a highly magnified image, it is possible for young and old alike to easily guide the platform's working surface so that the image of a portion of a line of print remains horizontal and does not drift up or down on the TV monitor as the working surface is moved to the left or right.

The friction mechanism of the X-Y Platform is shown in Fig. 9. The adjusting

[4] The steel sheet permits magnets to be used to hold one or more sheets of paper flat and in place on the upper face of the working surface. Genensky has found that while this is a viable technique for holding paper in place, it is no better than, and perhaps inferior to, using a heavy steel bar.

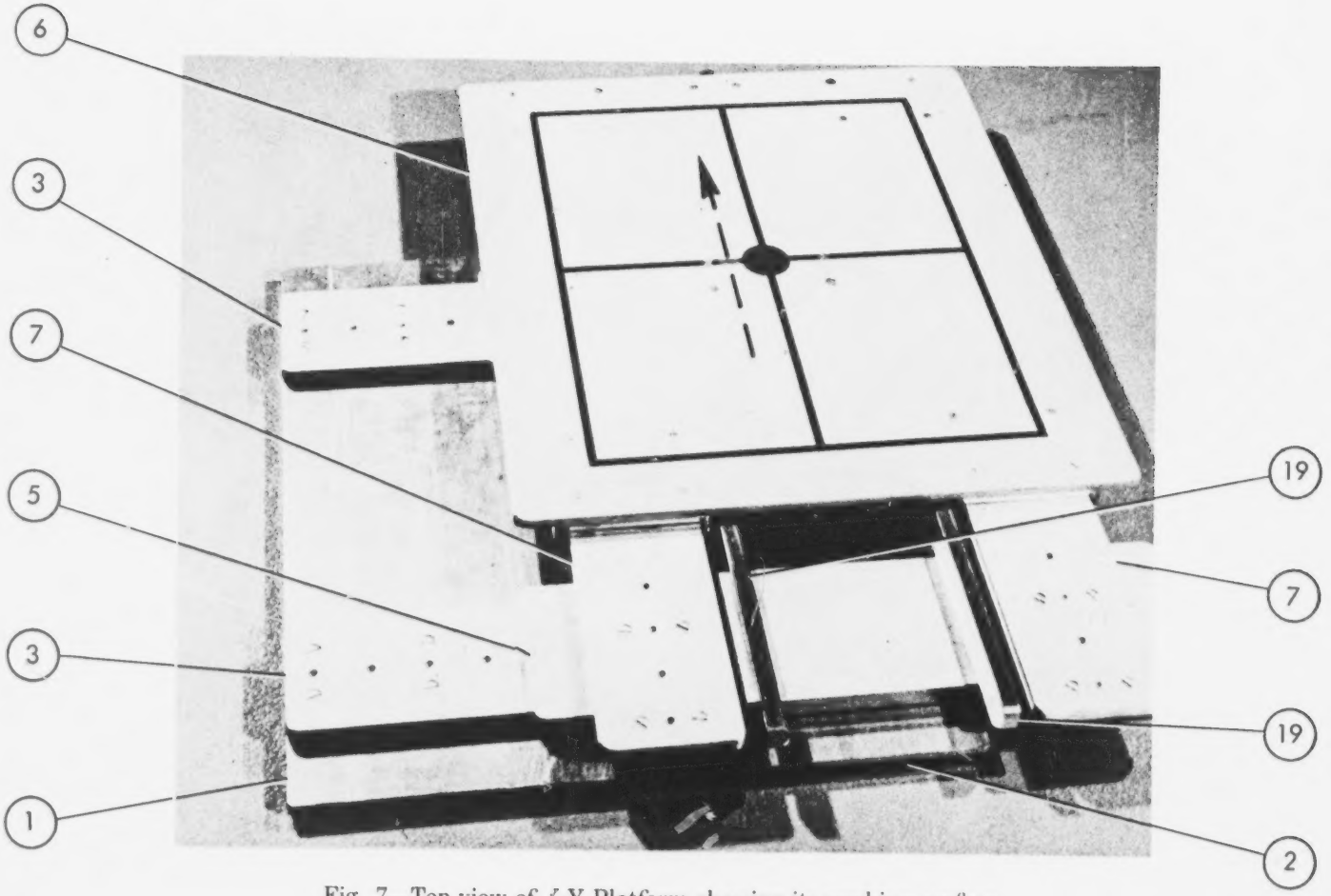

Fig. 7—Top view of X-Y Platform showing its working surface displaced to the right and the rear

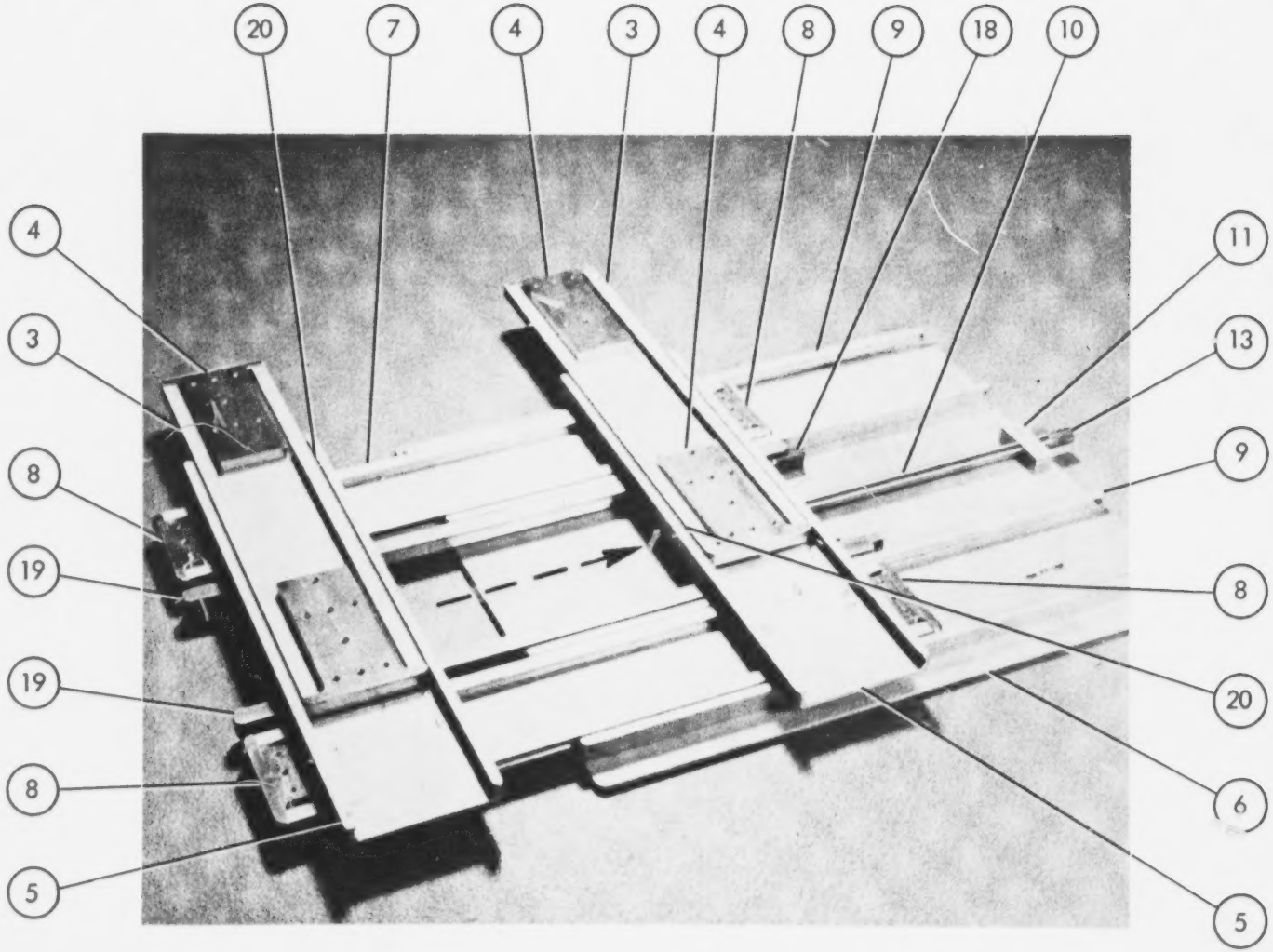

Fig. 8—X-Y Platform lying on its working surface (the base plate has been removed to show details of the drawer slide construction)

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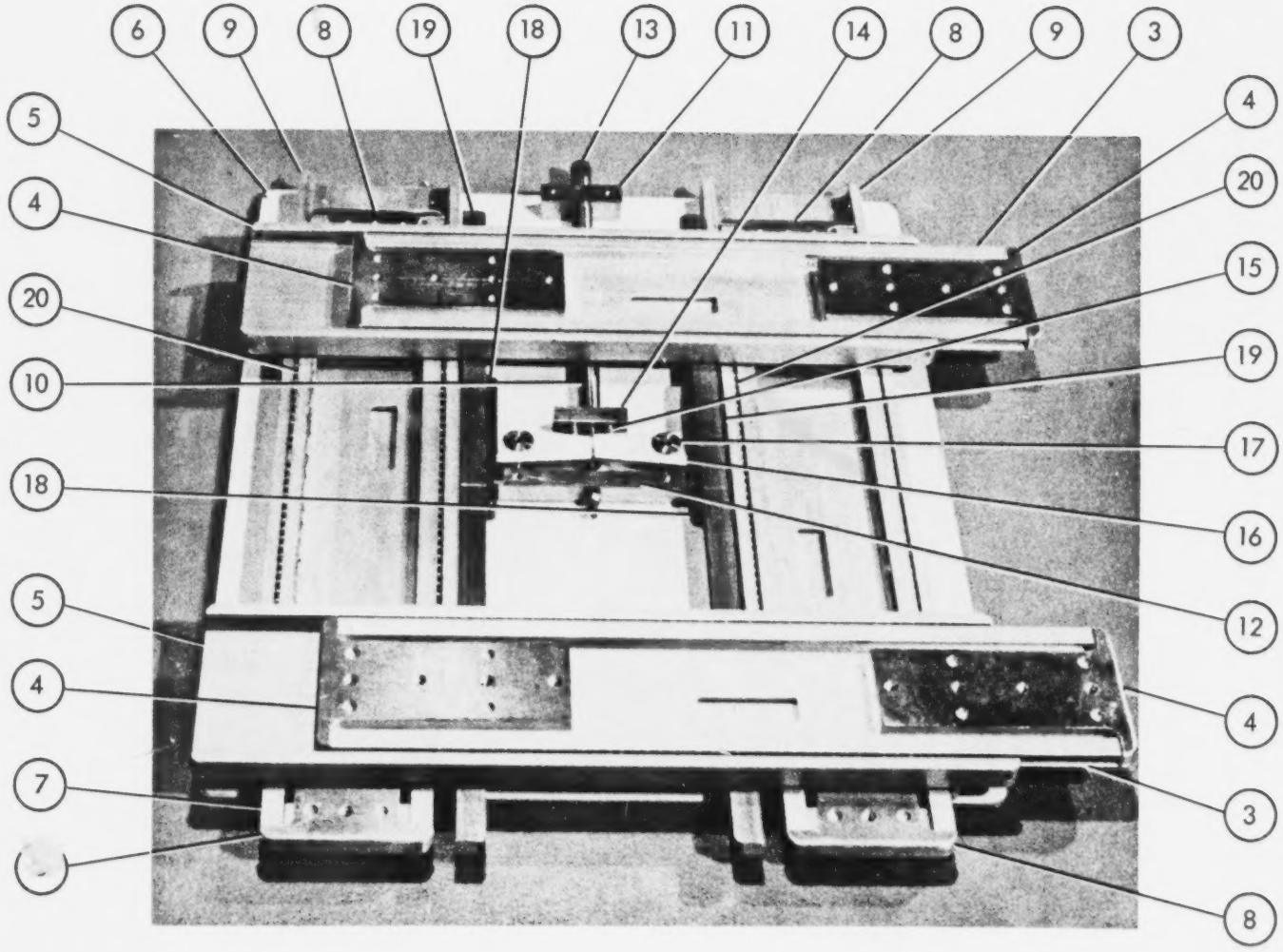

Fig. 9—X-Y Platform lying on its working surface (the base plate has been removed to show details of the braking system and drawer slide construction)

rod (10) is supported by the pillow block (11) and the anchor block (12). These blocks are screwed onto the bottom side of the working surface (6) and move with it. As the knob (13) of the adjusting rod is turned and the rod screws into the anchor block, it carries the spring bar (14) forward, compressing the springs (15) against the ends of the lever bars (16). This spring force is directed by the lever bars and pivot studs (17) to the brake shoes (18), forcing them against the brake rails (19). As the spring and brake shoe assembly is moving with the working surface, and the brake rails are fixed, this results in the desired friction during the line-to-line motion of the platform. The relatively large contact area of the brake shoes and the low spring constant give a smooth, even drag that can be increased by turning the knob.

When closed, both of the X-Y Platforms are 14 in. long, 12 in. wide, and about 1⅜ in. high. They weigh 14 lb and their moving parts weigh 8¼lb. The small height and the distribution of mass of these platforms appear to be desirable features. The thin construction permits a viewer to sit at a normal table or desk, move the platform's working surface (6), and manipulate reading and writing material on that surface with his hands, wrists, or arms located in natural and comfortable positions. The mass or weight of the platform and its distribution allow the viewer to maintain full control of the motion of the working surface. Genensky reports that these features, coupled with ample friction applied to the drawer slides governing the line-to-line motion of the working surface, permit him to work comfortably with the platform for hours at a time. At times he is not even conscious of the presence of the platform, or that he is manipulating it while reading or writing. We must confess that we were surprised that the partially sighted preferred to work with a fairly massive X-Y Platform rather than with a light one.

A list of design criteria for an X-Y Platform is given in Sec. VIII.

READING AND WRITING WITH THE X-Y PLATFORM

To read with the X-Y Platform, the viewer first *(a)* places his reading material on the working surface, *(b)* centers and aligns it with respect to the edges of that surface, *(c)* pulls the working surface toward him until the top line of the material is visible and at a convenient height on the monitor screen, and *(d)* moves the working surface to the right until the left margin of the reading matter is clearly visible on the screen. He then *(e)* moves the working surface to the left and reads the words on the top line of the page as they pass by on the monitor screen. When he comes to the end of the line, he *(f)* pushes the working surface rapidly to the right until the left margin is again visible on the screen. He *(g)* pushes the X-Y Platform away from him until the second line has moved to the height on the screen that had previously been occupied by the first line. He *(h)* pulls the working surface to the left and reads the content of the second line. After completing the reading of that line, he *(i)* moves the working surface rapidly to the right until he sees the left margin. He repeats steps *(g)* through *(i)* for each successive line until he reaches the

bottom of the page. He then turns to the next page and repeats the procedure outlined above.

Figure 10 shows RANDSIGHT I equipped with an X-Y Platform for reading. Note that the operator is using an electronic window adjusted to present three lines of text while the right-hand monitor is set to display only one line of text. (The electronic window is described further in Sec. VI.)

To write with the X-Y Platform, the viewer first *(a)* places his writing pad or writing paper on the working surface, *(b)* centers and aligns it with the edges of that surface, *(c)* pulls the working surface toward him until the line on which he wishes to begin writing appears at a convenient height on the monitor screen, and *(d)* moves the working surface to the right until the left margin of the writing material is clearly visible on the screen. He then *(e)* places his nonwriting hand on the working surface and on an edge of the writing pad or paper, *(f)* moves his pencil or pen up the left-hand margin of the writing material until he sees it on the monitor screen, and *(g)* positions the pen or pencil to commence writing.

The actual process of writing may appear complex but in reality is very simple and is mastered in a matter of minutes by most viewers. It is accomplished as follows: The viewer *(h)* writes holding his pen or pencil in his writing hand and *(i)* pulls the working surface to the left with his other hand at a rate that permits the writing end of his pen or pencil to be seen on the monitor screen at all times. Genensky finds it convenient to move the working surface to the left at a rate that just compensates for the rate at which he is writing. This permits him to view the writing end of his pen or pencil at roughly the same place on the monitor screen whenever he is actually putting symbols on paper.

On reaching the end of a line, the viewer *(j)* lifts his pen or pencil from the paper and with his other hand *(k)* pushes the working surface to the right until the left margin of the writing pad or paper is clearly visible on the monitor screen. Using his writing hand, he *(l)* pushes the working surface away from him until the next line on which he wishes to write is in the position previously occupied by the last line on which he wrote. Steps *(f)* through *(l)* are repeated until the viewer reaches the end of the page, and the whole process, starting with *(a)*, is repeated for each page until he completes his writing.

Figure 11 shows RANDSIGHT I equipped with an X-Y Platform being used for writing. Note that the operator is writing with his right hand and using his left hand to hold the writing tablet in place *and* to maneuver the working surface.

Fig. 10—X-Y Platform being used for reading in conjunction with RANDSIGHT I

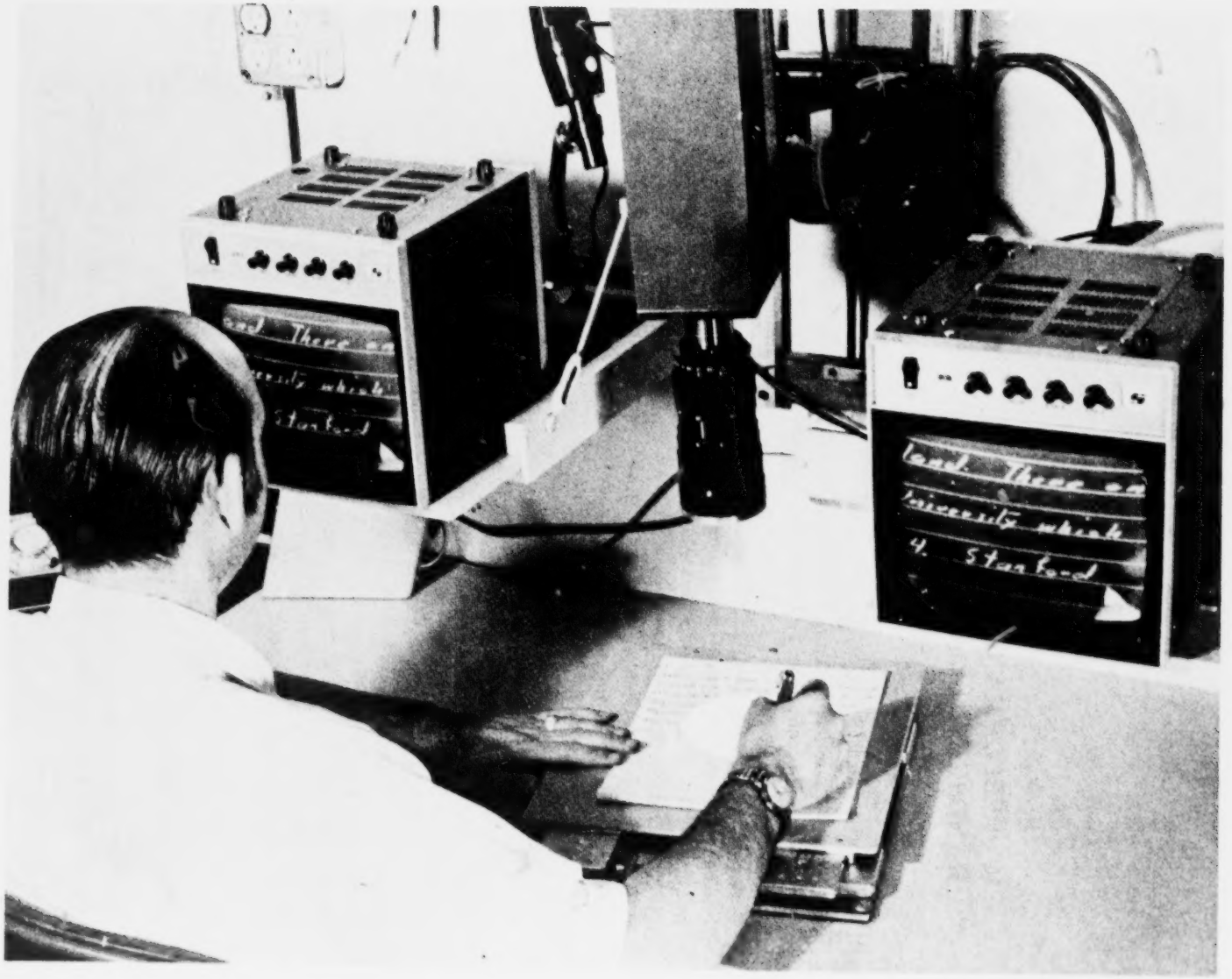

Fig. 11—X-Y Platform being used for writing in conjunction with RANDSIGHT I

V. PERFORMANCE OF PARTIALLY SIGHTED WITH RANDSIGHT I EQUIPPED WITH AN X-Y PLATFORM

Although our grant from the Social and Rehabilitation Service did not require us to go beyond proof testing RANDSIGHT II, we did engage in an informal testing program using RANDSIGHT I.[1] The stimulus for that program was due in part to the many requests from ophthalmologists, optometrists, educators, and rehabilitation personnel that we permit their partially sighted patients and clients to examine and try our RANDSIGHT equipment. Many other requests for help and advice were generated by George A. W. Boehm's *Reader's Digest* article on our RANDSIGHT research (see Ref. 9). We were delighted with the opportunity this gave us to assist the partially sighted and to gather valuable data regarding this group and its performance with our RANDSIGHT equipment.

We tried to see as many as possible of the partially sighted who directly or indirectly sought our assistance and who were able to come to our offices. Each partially sighted person (hereafter referred to as "subject") who visited our facility was given about two hours of our time, and with few exceptions, each of them made but one visit to our offices. We would have liked to have seen many of our subjects two or more times, but the demands for our time and attention were too great to permit us to do this. Our records show that during the last 16 months, we have seen over 120 subjects and we have communicated by mail or phone with over 5000 other people who have visual problems or have family or friends who are partially sighted.

Although our testing program was informal, it did develop a somewhat predictable format, which is described below.

TEST PROCEDURE

First, the subject was asked to supply such data as his name, address, age, and sex; the nature of his visual disorders, when those disorders were known or thought

[1] RANDSIGHT I as it currently exists and as it existed during this testing program is described in App. B.

to have originated, and when they were first detected; the extent of the subject's formal education and whether he was a student, employed, unemployed, or retired. This data gathering was usually followed by Genensky giving a detailed and frank description of his own visual disorder, including its history, the extent of his visual field, and the level of his visual acuity. Thus, the subject was made aware that he was dealing with someone who was himself partially sighted and hence understood firsthand what it was to be visually impaired. In most cases, it turned out that the subject's visual acuity exceeded Genensky's. If the subject or family or friends who accompanied him to our offices wanted additional information regarding Genensky —for example, his education, career, or methods of coping with and integrating into the sighted society—that information was gladly provided. Our policy of trying to answer all questions played an important part in placing the subject at his ease, particularly if he had more residual vision than Genensky. For in that case, the subject was able to make a comparison that often led him to conclude that, visually speaking, he was much less impaired than he had previously thought, and as a result might be in a better position to cope with his partial eyesight. Our open exchange of vision information also helped the subject's family and friends to grasp a more realistic understanding of his visual capability; consequently, they were in a better position to provide him with the help and assistance that he *actually* needed rather than the help and assistance they had *perceived* he needed.

The subject's distance visual acuity was measured at 5 or 10 ft, using such tests as the Feinbloom "Distance Test Chart for the Partially Sighted," the Good-Lite "Symbols for 10 Feet," or the "Sloan Letters for 20 Feet," and the results were converted to the equivalent Snellen acuity at 20 ft. Whenever possible we used the Feinbloom chart because, at 5 or 10 ft, almost all of our subjects could resolve at least one or two numbers on that chart. Had we used the conventional approach of asking our subjects to read at 20 ft from a chart designed for persons with relatively good vision (e.g., the "Snellen" types), most of our subjects would have had to report that they could not resolve a single symbol. We firmly believe that the partially sighted, like the normally sighted, do not wish to be placed in a position in which they are guaranteed to fail. Like the fully sighted, they respond positively to an opportunity to achieve, and our entire test procedure is designed to give them every chance to succeed. We, of course, were not always successful, because some subjects do not possess the mental, mechanical, or visual capacity needed to carry out the various tasks and operations involved in our procedure. Nevertheless, we were continually on the alert to do all we could to encourage and assist our subjects.

Visual acuity was measured for both the left and right eye with and without corrective lenses. The only corrective lenses used in the procedure were those that the subject was wearing or happened to bring with him. If he did wear or carry corrective lenses, we tried to ascertain how long he had had them, how often he wore them, and for what purposes he used them.

If the subject's visual acuity appeared to be distinctly better than Genensky's, and if we believed that it would be beneficial to him or a member of his immediate family, we asked the subject to administer the acuity test he had just completed to Genensky. The effect of this technique is often very gratifying, because the subject,

his relatives, as well as others in the room are greatly encouraged by this concrete evidence that the subject can in fact see better than Genensky, and thus, in most cases, need not resign himself to coping with the sighted world as do the functionally blind, but rather in ways that make maximum use of his residual vision.

On completing the visual acuity measurements, the subject was asked to look through a set of clear and colored transparent plastic squares in the direction of the overhead fluorescent lighting and to report for each square the color he observed. Using this test, it is remarkable how many partially sighted people have very good color discrimination. However, this test fails to measure how well the partially sighted are able to discriminate color in the presence of ordinary room lighting or illumination that falls below that normally encountered in the office or the home. Because the discrimination threshold of the partially sighted tends to be higher, it is likely that under ordinary conditions the color discrimination of many partially sighted will prove to be distinctly inferior to that of the "normally" sighted.

The subject was then introduced to RANDSIGHT I, equipped with an X-Y Platform. This usually involved describing the instrument's various parts and how they interact. Sometimes an explanation was also given of such questions as why an electro-optical device is able to produce a brighter, higher contrast image than a pure optical device, why it is vitally important to design an instrument that the partially sighted can use naturally and comfortably, and what contrast reversal and an electronic window are and how they benefit some of the partially sighted.

The subject was shown how to read with the help of the device and was given an opportunity to read with it himself. After he had read for about 5 minutes, several measurements were made: the linear magnification of the print viewed on the monitor screen, the distance between the subject's eyes and the monitor screen, and the rate at which he read (measured in words per minute). The first two measurements permitted us to calculate the effective magnification at which he read. Usually these measurements were made two or three times during the period the subject was using RANDSIGHT I to read. In most cases, it was found that the effective magnification does not change appreciably, but the reading rate tends to increase and sometimes quite dramatically, giving the distinct impression of a learning or relearning process. Some of the increase in reading rate may be due to improvement in subject adroitness in handling the instrument, and some of it is probably due to the subject actually learning or relearning to read visually. It should be noted that all measurements of the subject's reading rate were made with him reading aloud.

If the subject failed to read well with RANDSIGHT I, we did not automatically conclude that his poor performance was due entirely to his poor vision. In such cases, we inquired as to when the subject last read printed or handwritten material, how he and/or his relatives and friends would rate his reading ability, and what kinds of material he had read in the past. Such questions sometimes led us to conclude that we were not using reading material appropriate for the subject, and when we changed to more suitable material, we frequently found that the subject's interest in trying to read improved and his reading rate increased.

Usually we would have a subject read double-spaced typewritten material, newsprint, or graded readers. However, we did not discourage the subject from

reading the material that he had brought with him, which generally consisted of reading matter that he considered important to his education, vocation, or leisure. Among the materials brought to our offices were law books, programming manuals, geographies, novels, magazines, and telephone directories. It should be noted that we rarely made our reading measurement using the subject's own reading matter, because we wished to avoid the possibility of obtaining abnormally high reading rates resulting from the subject's prior exposure to the context of the reading matter.

After we completed our measurements with respect to reading, we asked the subject if he would like to try to write with the help of RANDSIGHT I. Most subjects were immediately willing, although some found reading with the instrument so enjoyable that they asked if they might continue to keep reading. We, of course, tried to comply with this request, but the fact that we could devote only two hours to a subject, and rarely ever saw him a second time, often forced us to ask the subject to stop reading sooner than we would have liked to.

Some subjects showed no desire to try to write. This may be due to several causes: The subjects may never have learned to write in the sighted sense of that operation; they may perceive that their handwriting is so poor that they are not willing to show it to others; they may have forgotten how to write; or although they know how to write, they may be unwilling to do so when asked. The latter three reasons appear to be particularly applicable to the elderly. If a subject, no matter what his age may be, has psychologically dropped out of the sighted or partially sighted community, he may refuse to try to write because he no longer possesses the motivation needed to succeed in the sighted world.

Subjects who expressed interest were given a demonstration of how to write with the help of the instrument, and they were then permitted to write themselves. We suggested that they first write or print the alphabet, whereupon they were encouraged to write words and sentences—usually of their own choosing. While the subject was writing, measurements were made of the distance between his eyes and the monitor screen, and when he stopped writing the linear magnification of the image of his handwriting was determined. Judgments of the quality of the subject's handwriting were made and, in most cases, a sample of the subject's handwriting was affixed to our record of his visit.

We found that some subjects, without the aid of optical or electro-optical instruments and without actually seeing what they were doing, were able to write fairly satisfactorily with a pen or pencil. However, when they were asked to write down a column of numbers and then to add them without the aid of RANDSIGHT I, they were unable to do so. This is due to the fact that in general the successful execution of this sequence of operations requires the use of at least some residual vision. When these subjects were asked to carry out these operations using RANDSIGHT I, they frequently succeeded, and came to realize, or perhaps were more prepared to admit, that without the aid of an optical or electro-optical device they were unable to both write and see what they were writing or had written.

Some subjects brought with them their own writing materials, for example, a ledger, a programming chart, or a checkbook. We were delighted when this occurred,

and we did all we could to show them how they could use RANDSIGHT to work with these materials.

If time permitted, if the subject appeared interested, or if we believed it worthwhile, we explained to him how binoculars have helped Genensky to do such things as read a chalkboard while seated in a classroom, read charts or slides in the course of a lecture, determine the status of a traffic signal, locate merchandise in a store, and watch movies, plays, TV, and sports events. We then showed the subject how to use our wide-angle 7 by 35 binoculars, and encouraged him to try to use them to read printed and handwritten symbols, words, and sentences that we wrote on a chalkboard. With the help of the binoculars, many subjects were able to resolve printed and handwritten material when it was 1 or 2 in. high at distances as great as 15 ft from the chalkboard. Students and adults of working age, who succeeded in using the binoculars, were particularly excited about how they might be able to use this versatile visual aid to further their education or career.

We have been surprised, and frankly shocked, to learn that few clinicians are aware of how valuable a pair of binoculars can be to a person with limited eyesight. As in the case of closed circuit TV systems for the partially sighted, we have done all we can to inform clinicians, the partially sighted, and the general public about the potential value of this readily available and too-long-ignored visual aid.

TEST RESULTS

The records of 81 subjects who have used RANDSIGHT I since it was first equipped with an X-Y Platform were selected for analysis. These were chosen on the basis of the following criteria:

1. The records contained sufficient data concerning the subject's visual disorders.
2. The subject had not been exposed to a closed circuit TV system for the partially sighted before visiting our offices.
3. The records included the subject's age, his sex, and the approximate date of onset of his visual disorders.

It must be emphasized that these subjects were not chosen at random from the overall partially sighted population. They were brought to our attention either by clinicians, educators, or rehabilitation personnel, or by themselves, their family, or friends as a result of having read or heard about our research in popular or professional articles. Most of those who came to see us were probably either highly motivated or were brought to our offices by family or friends who were anxious to help them and have them succeed.[2] Further, those who came to see us were either able

[2] In a few instances, we noted that the subject was not highly motivated and that the members of his family who accompanied him appeared to have the attitude that once they had brought him to see us, their job was done, and the sooner they and he could leave the better.

to pay for their transportation, or their family or friends were able to bear that expense. For many of these people, transportation costs ran quite high, as they came from all parts of the nation, as well as from countries as distant as Chile and India. However, even though our subjects were not chosen at random and probably underrepresent partially sighted persons who lack motivation or have low incomes, they do represent a broad cross-section of the partially sighted with respect to such factors as age, education, visual acuity, and ocular pathology. Further, no attempt was made to filter the flow of subjects other than to discourage persons who had no residual vision whatsoever in both eyes. In view of these facts, we believe that the results of our informal testing are of value and worth reporting and analyzing.

Table 2 contains a detailed breakdown of subject performance with RANDSIGHT I. Column 1 contains the code number assigned to each subject. Because we often refer to Genensky's experience with, and comments and conjectures about, our RANDSIGHT equipment, we decided to assign him the code letter "G" and to include information about him and his *current* performance with RANDSIGHT I as the first row in this table. No data concerning him or his performance appear in subsequent tables; nor are his data used in the observations made in the next section.

Column 2 gives the subject's eye disorder(s) as stated by his physician or, that not being available, by the subject, his parent, or guardian.[3] Column 3 gives the subject's sex, and column 4, his age. Column 5 shows whether the subject has any gross scotomas (central or peripheral).

Columns 6 and 7 give the subject's best distance visual acuity in the right (R) and left (L) eye, respectively. Here "best" means the largest numerical value of distance visual acuity measured for each eye with or without corrective lenses and recorded in equivalent Snellen acuity at 20 ft. The symbols FC and LP that appear in columns 6 and 7 stand for finger counting and light perception, respectively. The blank spots in those columns indicate that no distance visual acuity measurement was made; either we failed to make the measurement or we did try to make it but were unable to obtain a reliable value. In some cases, the subject tended to favor one eye to such an extent that it soon became clear that he was not using the other eye. When this occurred, we sometimes decided not to measure the acuity in the nondominant eye.

Columns 8 through 12 present data regarding the results of the subject's reading with RANDSIGHT I. Column 8 gives the distance in inches between the subject's eyes and the monitor screen. This is referred to as the working distance (WD). Column 9 shows the linear magnification (LM) of the image on the monitor screen to the printed material being read. Column 10 gives the effective magnification (EM), which is computed from the relationship

$$EM = (16)(LM)/(WD), \quad (1)$$

using the working distance (WD) and linear magnification (LM) given in columns 8 and 9, respectively. Column 11 shows the best recorded reading rate in words per

[3] Occasionally, the subject, parent, or guardian gave information regarding the visual disorder(s) in lay language; this information has been recorded here in more conventional medical terminology.

Table 2

PERFORMANCE OF PARTIALLY SIGHTED WITH RANDSIGHT I
(December 1970 to March 1972)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
					Best Distance Acuity with or without Rx		Reading					Writing			
Code No.	Visual Disorder	Sex	Age	Scotomas	R	L	WD	LM	EM	Rate	UF	WD	LM	EM	UF
G[a]	*Corneal opacities, glaucoma*	*M*	*44*	*No*	*20/750*	*Nil*	*1*	*5x*	*80x*	*125*	*S*	*1*	*2x*	*32x*	*s*
1	Macular degeneration, retinitis	M	61	No	20/200		7	6x	14x	55	S	8	2½x	5x	s
2	Macular degeneration, retinal hemorrhages	M	71	Yes	20/300	20/500	6	10x	27x	50	S	7	2½x	6x	s
3	Optic nerve atrophy	M	88	Yes	20/400		9	11½x	20½x	10?	M	5	5x	16x	u
4	Macular degeneration, retinal hemorrhages	F	83	Yes	20/400	20/480	4½	6½x	23x	60	S'	6	4x	10½x	s
5	Glaucoma, macular degeneration	M	61	No	20/100	20/100	7	3½x	8x	50	S	6	3½x	9½x	s
6	Chorioretinitis	M	19	No	20/100	FC	5	3½x	11x	31	S	6	2x	5x	s
7	Mild albinism	F	34	No	20/200	20/200	4	4x	16x	100	S	4	3x	12x	m
8	Macular degeneration	M	79	Yes	20/550	20/550	6	10x	27x	30	M	6½	2x	5x	m
9	Macular degeneration	M	40	Yes	20/200	20/250	12	4x	5½x	115	S	9	1½x	2x	s
10	Retinal detachment, macular degeneration	F	~60	Yes	20/480	20/480	8	4x	8x	31	S				

[a]These data for Genensky are listed for reference purposes only.

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Table 2--continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
					Best Distance Acuity with or without Rx		Reading					Writing			
Code No.	Visual Disorder	Sex	Age	Scotomas	R	L	WD	LM	EM	Rate	UF	WD	LM	EM	UF
11	Scarred Retina	F	38	Yes	20/1200	20/900	3½	10x	46x	20	M	4	6x	24x	u
12	Macular degeneration, retinal hemorrhages	M	77	Yes		20/400	6	8½x	23x	35	S	4	4x	16x	s
13	Optic nerve atrophy (partial)	F	13	Yes	20/400	20/400?	4	4½x	18x	90	S	2½	2x	13x	s
14	Sclerosis of ophthalmic arteries	M	58	Yes	20/800		9	10x	18x	60	S	9	4x	7x	s
15	Myopic degeneration	M	~60	No	20/200	20/200	6	5½x	15x	70	S	4½	2½x	9x	s
16	Optic nerve injury (possible)	F	38	Yes			4	13x	52x	(b)	M	4?	7x?	28x?	m
17	Diabetic retinopathy, cataracts	M	52	Yes	20/650		5	2½x	8x	?	U				
18	Glaucoma, cataracts, macular degeneration?	F	85	Yes	FC	LP	5	3x	9½x	1	U				
19	Retinitis Pigmentosa	M	32	Yes		20/600	3	8x	43x	2	U	4	8x	32x	u
20	Retinal hemorrhages	M	72	Yes	20/800		10	16x	25½x	30	M	6	2½x	6½x	m
21	Stroke, glaucoma	M	50	?	20/1000	20/1000?	5	12x	39x	?	U	3	6x	32x	u
22	Macular degeneration	M	46	Yes	20/500	20/500?	4½	10x	35½x	90	S	4	5x?	20x?	s
23	Retinitis pigmentosa, cataracts	M	57	Yes	20/200	LP	14	7x	8x	1	U				
24	Optic nerve atrophy	M	43	Yes	20/500	20/500	6	6x	16x	40	S	6½	1½x	3½x	s

[b] The subjects represented in this line of the table rated an M for reading, but the exact rate at which they read could not be determined. It ranged between 3 and 30 wpm. This was due to one of several causes: the subjects were either too nervous to perform consistently, or they tired easily, or they showed marked signs of senility.

Table 2--continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Code No.	Visual Disorder	Sex	Age	Scotomas	Best Distance Acuity with or without Rx		Reading					Writing			
					R	L	WD	LM	EM	Rate	UF	WD	LM	EM	UF
25	Brain tumor (optic nerve)	M	21	Yes	20/200	LP	3½	5x	23x	70	S	3½	3x?	13½x?	s
26	Uveitis	M	50	No	20/200		16	3½x	3½x	50	S	6	1½x	3½x	s
27	Retinal sclerosis, cataracts	M	90	Yes	20/400	20/400	7	18x	41x	(b)	M	4	2½x	10x	m
28	War injury to eye	M	21	Yes	20/200		1	12x	192x	35	S	5	1½x	5x	s
29	Diabetic retinopathy, retinal circulation, Bell's palsy	M	73	Yes			4	10x	40x	60	S				
30	Retinopathy	M	57	Yes	20/480	20/240	7	10x	23x	48	S	8	2x	4x	s
31	Macular degeneration	M	84	Yes	20/500?	20/500	8	9x	18x	20	M	8	2x	4x	m
32	Macular degeneration	M	52	Yes	20/480	20/240	6	8x	21½x	30	M	5	2x	6½x	m
33	Glaucoma, cataracts	M	82	Yes		20/1150	2	8x	64x	30	M	3	2½x	13½x	m
34	Optic nerve atrophy	F	7	?	20/320	20/320	12	5x	7x	?					
35	Congenital optic nerve atrophy	M	7	No	20/100	20/160	6	2x	5½x	?					
36	Macular degeneration	M	60	Yes	20/400	20/1200	5	6x	19x	25	M	3	3x?	16x?	m
37	Cataracts, retinopathy	M	~70	Yes	20/480	20/240	12	4½x	6x	43	S	7	3x	7x	s
38	Glaucoma	M	57	No	20/550	LP	6	12½x	33½x	15	M	4	6½x	26x	m
39	Cataracts	M	79	?		20/270	5	4x	13x	(b)	M	2	2x	16x	m
40	Cataracts, detached retina	M	76	Yes	20/1400	20/300	7	11½x?	26½x?	(b)	M	3	2x	11x	m

[b] See note b on second page of table.

Table 2--continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Code No.	Visual Disorder	Sex	Age	Scotomas	Best Distance Acuity with or without Rx		Reading					Writing			
					R	L	WD	LM	EM	Rate	UF	WD	LM	EM	UF
41	Glaucoma, cataracts	F	70	Yes	Nil	20/200	14	4½x	5x	50	S	6	2x	5½x	s
42	Macular degeneration, arterial sclerosis (eye)	M	69	No	20/240	20/350	6	6x	16x	50	S	4	2x	8x	s
43	Glaucoma	F	58	No	Nil	20/650	5	4x	13x	50	S	6	3x	8x	s
44	Macular degeneration	F	75	?	LP	20/480	6	12x	32x	30	M				
45	Macular degeneration	F	54	?	20/350	20/350	11	5x	7x	64	S	6	3x	8x	s
46	Retinitis pigmentosa	M	25	?		20/450	7	9x	20½x	?	U				
47	Macular degeneration	F	46	No	20/400	20/400	9	4x	7x	33	S	6	1½x	4x	s
48	Retinitis pigmentosa	M	45	No	20/400	20/200	5	4½x	14½x	35	S	5	2x	6½x	s
49	Macular degeneration	M	69	No	20/320	20/200	11	4x	6x	90	S	12	2x	3x	s
50	Macular degeneration	F	69	?	20/400	20/1200	5	9x	29x	35	S	5	3½x	11x	s
51	Retinitis pigmentosa, cataracts	F	44	Yes	20/120	20/160	8	1½x	3x	120	S	11	1½x	2x	s
52	Retrolental fibroplasia	F	9	Yes	20/50	20/480	6	4x	11x	190	S	?	?	?	s
53	Macular degeneration	M	76	No	20/400	20/400	6	2½x	7x	(b)	M				
54	Congenital retinoschisis	M	23	No	20/400	20/240	4	4x	16x	114	S	?	?	?	s
55	Macular degeneration	M	75	Yes	20/50	20/60	12	7x	9x	60	S	6	1½x	4x	s
56	Glaucoma, diabetic retinopathy, cataract	M	~70	Yes	LP	20/200	5	4½x	14½x	45	S	4	2x	8x	s

[b] See note b on second page of table.

Table 2--continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Code No.	Visual Disorder	Sex	Age	Scotomas	Best Distance Acuity with or without Rx		Reading					Writing			
					R	L	WD	LM	EM	Rate	UF	WD	LM	EM	UF
57	Optic nerve atrophy, cataracts	M	88	Yes	Nil	20/560	5	5½x	17½x	35	S	?	?	?	s
58	Retinitis pigmentosa	M	26	?	20/150	20/240	13	2½x	3x	17	M	15	2x	2x	m
59	Macular degeneration, herpes zoster (eye)	M	80	?	20/400	20/400	7	12x	27½x	20	M				
60	Diabetic retinopathy	M	~45	Yes	Nil	20/240	6	7x	19x	60	S	4	3x?	12x?	s
61	Glaucoma, stroke, circulatory (retinal)	M	55	Yes	20/1200	20/1200?	3	12x	64x	(b)	M	3	6x	32x	m
62	Optic nerve atrophy	M	46	Yes	20/750		5	10x	32x	86	S				
63	Cataracts, iritis	F	70	Yes		FC	8	22x	44x	?	U				
64	Diabetic retinopathy, glaucoma, cataracts	F	58	Yes?	20/320	Nil	?	?	?	20	M				
65	Macular degeneration, retinal detachment	F	50	Yes	20/450	20/450	8	4x	8x	33	S				
66	Cataracts (congenital), Down's syndrome	M	11	No	20/150	20/150	6	1½x	4x	31	S				
67	Macular degeneration	M	61	No	20/150	20/400	8	8x	16x	70	S	8	2½x	5x	s
68	Macular degeneration	M	76	Yes	20/800	Nil	4	10x	40x	?	U				
69	Cataracts (congenital)	M	18?	Yes	LP	20/1300	2	3½x	28x	37	S	2	2x	16x	s
70	Diabetic retinopathy	M	34	Yes	LP	20/1200	6	12x?	32x?	(b)	M	6	4x	11x	m
71	Retinitis pigmentosa	M	29	Yes?	20/900	20/200	15	4½x	5x	70	S	8	1½x	3x	s

[b] See note b on second page of table.

Table 2--continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
					Best Distance Acuity with or without Rx		Reading					Writing			
Code No.	Visual Disorder	Sex	Age	Scotomas	R	L	WD	LM	EM	Rate	UF	WD	LM	EM	UF
72	Macular degeneration	M	~65	Yes	20/150	20/150	12	3½x	5x	75	S	8	1½x	3x	s
73	Retinitis pigmentosa	M	35	Yes	20/150	20/300	18	5x	4½x	(b)	M	18	1½x	1½x	m
74	Glaucoma, retinal detachment	M	~55	No	LP	20/500	2	2x	16x	55	S	10	3x	5x	s
75	Diabetic retinopathy, cataracts	M	52	Yes	20/800	LP	12	10x	13½x	?	U				
76	Optic nerve atrophy (injury)	F	38	Yes	20/400?	20/400	4	13x	52x	(b)	M	4?	5x?	20x?	m
77	Macular degeneration	M	~72	Yes	Nil	20/1500	6	5x	13½x	?	U				
78	Macular degeneration	M	78	No	20/320	20/320	8	10x	20x	?	U				
79	Macular degeneration	M	~44	Yes	20/200	20/200	6	4x	11x	31	S	?	?	?	s
80	Cataracts, retinal hemorrhages	F	75	Yes	20/1500	20/1200	?	?	?	?	U				
81	Uveitis, retinal detachment	F	65	Yes		20/400	6	6½x	17½x	31	S	?	?	?	s

[b] See note b on second page of table.

minute (wpm). Column 12 gives the subject's utility factor (UF) for reading. The UF takes on three values: "S" when the subject could read 31 or more words per minute, "M" when he could read more than 2 words per minute but no more than 30 words per minute, and "U" when he could read no more than 2 words per minute.

Columns 13 through 16 present data regarding the results of the subject's writing with RANDSIGHT I. Columns 13, 14, and 15 contain data similar to that given in columns 8, 9, and 10, respectively, only here they refer to writing rather than reading. The values of WD and LM in Eq. (1) are obtained from columns 13 and 14, respectively (rather than from columns 8 and 9). Column 16 gives the utility factor (UF) for writing and, as in the case of the UF for reading, it also takes on three values: "s" if the subject's handwriting using RANDSIGHT I was legible to the subject as well as to others and was reasonably well spaced, "m" if his handwriting was legible at least by others and was not well spaced, and "u" if he could not write at all or wrote so little or so poorly that a reasonable observer would have to conclude that either he could not write with the aid of the instrument or that he lacked the interest or incentive needed to write successfully with the device.

The reader will note that for subjects 52, 54, and 57 the WD and LM are not known; yet for these people the UF takes on the value "s." This is due to the fact that we obtained a large enough sample of their writing to judge its quality, but due to their insistence on frequently and unpredictably varying the linear magnification and their location relative to the monitor, we were unable to obtain satisfactory values of LM and WD.

Table 3 indicates how many subjects in all and how many subjects in each decade of life are male or female, have visual acuities that fall in specified ranges, scored S, M, or U when reading with RANDSIGHT I, and rated s, m, or u when writing.

Table 4 gives the number of subjects having one and only one of each of the six most frequently reported visual disorders, and the number that have one or more other visual disorders as well. For each of these groups, the table also gives the number who rated S, M, or U for reading and s, m, or u for writing.

Table 5 gives for reading and writing the number of subjects who carried out these operations within specified linear magnification ranges.

For specified effective magnification ranges, Table 6 gives data similar to that given in Table 5.

Table 7 indicates the number of subjects whose reading rate fell within specified limits.

Table 8 gives for reading and writing the number of subjects who carried out these operations at working distances that fell within specified ranges.

SOME OBSERVATIONS ON TEST RESULTS

Thirty of the 81 subjects had more than one visual disorder, and the four most prevalent visual disorders among our 81 subjects were macular degeneration (29), cataracts (18), glaucoma (10), and optic nerve involvement (10). (See Tables 2 and 4.)

Table 3

AGE DISTRIBUTION OF PARTIALLY SIGHTED SUBJECTS IN TERMS OF SELECTED CHARACTERISTICS

Characteristic	Total Subjects	Age of Subject (years)									
		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
Sex											
Male	59	1	3	6	3	7	11	8	14	5	1
Female	22	2	1	-	4	2	4	3	4	2	-
Total	81	3	4	6	7	9	15	11	18	7	1
Best Visual Acuity (right eye and/or left eye)											
20/50 to 20/100[a]	5	2	1	-	-	-	-	1	1	-	-
20/100 to 20/200	20	-	1	4	2	4	2	5	2	-	-
20/200 to 20/300	9	-	-	1	-	1	2	1	4	-	-
20/300 to 20/400	16	1	1	-	1	1	2	3	3	3	1
20/400 to 20/500	8	-	-	1	-	2	2	1	1	1	-
20/500 to 20/600	4	-	-	-	1	-	1	-	1	1	-
20/600 to 20/700	2	-	-	-	-	-	2	-	-	-	-
20/700 to 20/800	5	-	-	-	-	1	2	-	2	-	-
20/800 to 20/900	1	-	-	-	1	-	-	-	-	-	-
20/900 to 20/1000	1	-	-	-	-	-	1	-	-	-	-
20/1000 to 20/2000	6	-	1	-	1	-	1	-	2	1	-
Unknown/LP/FC	4	-	-	-	1	-	-	-	2	1	-
Total	81	3	4	6	7	9	15	11	18	7	1
Reading Performance											
S	45	1	4	4	1	9	7	10	7	2	-
M	22	-	-	1	5	-	4	1	6	4	1
U	12	-	-	1	1	-	4	-	5	1	-
?	2	2	-	-	-	-	-	-	-	-	-
Total	81	3	4	6	7	9	15	11	18	7	1
Writing Performance											
s	39	1	3	4	-	8	6	9	6	2	-
m	17	-	-	1	5	-	3	1	4	2	1
u	4	-	-	-	2	-	1	-	-	1	-
?	21	2	1	1	-	1	5	1	8	2	-
Total	81	3	4	6	7	9	15	11	18	7	1

[a]The actual value of the visual acuity is between the two values shown, e.g., less than 20/50 but greater than or equal to 20/100.

Table 4

READING AND WRITING PERFORMANCE OF SUBJECTS WITH THE SIX MOST PREVALENT VISUAL DISORDERS

Visual Disorders	No. of Subjects	Reading Performance				Writing Performance			
		S	M	U	?	s	m	u	?
Macular degeneration									
Alone	19	10	6	3	-	10	4	-	5
Plus other visual disorders	10	8	1	1	-	6	-	-	4
Total	29	18	7	4	-	16	4	-	9
Cataracts									
Alone	3	2	1	-	-	1	1	-	1
Plus other visual disorders	15	5	4	6	-	5	3	-	7
Total	18	7	5	6	-	6	4	-	8
Glaucoma									
Alone	2	1	1	-	-	1	1	-	-
Plus other visual disorders	8	4	3	1	-	4	2	-	2
Total	10	5	4	1	-	5	3	-	2
Optic nerve involvement									
Alone	9	4	3	-	2	3	2	1	3
Plus other visual disorders	1	1	-	-	-	1	-	-	-
Total	10	5	3	-	2	4	2	1	3
Retinitis pigmentosa									
Alone	6	2	2	2	-	2	2	1	1
Plus other visual disorders	2	1	-	1	-	1	-	-	1
Total	8	3	2	3	-	3	2	1	2
Diabetic retinopathy									
Alone	2	1	1	-	-	1	1	-	-
Plus other visual disorders	5	2	1	2	-	1	-	-	4
Total	7	3	2	2	-	2	1	-	4

Table 5

LINEAR MAGNIFICATIONS REQUIRED FOR SUBJECTS TO READ AND WRITE

Linear Magnification	No. of Subjects	
	Reading	Writing
1x to 2½x	7	32
3x to 4½x	23	14
5x to 6½x	13	7
7x to 8½x	8	2
9x to 10½x	14	--
11x to 12½x	9	--
13x to 14½x	2	--
15x to 16½x	1	--
17x to 18½x	1	--
19x to 20½x	--	--
21x to 22½x	1	--
Unknown	2	26
Total	81	81

Eighteen out of 29 subjects who had macular degeneration rated an S for reading and at least 16 scored an s for writing, whereas only 7 out of 18 subjects who had cataracts rated an S for reading and at least 6 scored an s for writing. Further, at least 40 percent of each visual group rated an S for reading. (See Table 4.)

Fifty-nine of the subjects were male and 22 female and their ages ranged from 7 to 90. Thirty-seven of them were 60 years old or older, 37 were between 20 and 59 years old, and only 7 were between 7 and 19 years old. (See Table 3.)

Fifty-three of the 81 subjects definitely had scotomas. These nonfunctioning areas in the visual field became known to us either through the subject's medical record, our observations of his behavior during the test procedure, our direct questioning, or through the subject's comments and remarks. A cursory examination was carried out to determine the general location and magnitude of scotomas, but our already overtaxed procedure did not permit us to carry out detailed tangent screen tests.

Only 2 of the 81 subjects (numbers 20 and 28) had suffered a visual loss within the year prior to visiting us. Although they rated UFs of M and m and S and s, respectively, they were nevertheless difficult to work with. This was no doubt due to their deep emotional involvement with themselves resulting from the negative change in their visual status.

The distance visual acuity (equivalent Snellen acuity at 20 ft) for the 81 subjects ranged between 20/50 and 0. Forty-five of the 81 subjects have acuities that are less than 20/100 but no worse than 20/400. (See Table 3.)

Table 6

EFFECTIVE MAGNIFICATIONS REQUIRED FOR SUBJECTS TO READ AND WRITE

Effective Magnification	No. of Subjects	
	Reading	Writing
1x to 2½x	--	4
3x to 4½x	5	9
5x to 6½x	7	11
7x to 8½x	9	6
9x to 10½x	2	4
11x to 12½x	3	5
13x to 14½x	7	3
15x to 16½x	7	5
17x to 18½x	5	--
19x to 20½x	5	2
21x to 22½x	1	--
23x to 24½x	4	1
25x to 26½x	2	1
27x to 28½x	4	1
29x to 30½x	1	--
31x to 32½x	3	3
33x to 38½x	2	--
39x to 44½x	6	--
45x to 50½x	1	--
51x to 60½x	2	--
61x to 70½x	2	--
192x	1	--
Unknown	2	26
Total	81	81

The linear magnifications selected for reading by the 81 subjects ranged between 1½x and 22x. Seventy-four of them preferred a linear magnification in the range 1½x to 12½x, and 23 in the range 3x to 4½x. In all but one case, smaller linear magnifications were preferred for writing than for reading, and 44 of the subjects wrote at linear magnifications ranging between 1x and 4½x. The effective magnifications relative to reading for 72 of the 81 subjects ranged rather evenly between 3x and 44½x. Relative to writing, 26 of the 55 subjects wrote at effective magnifications ranging between 3x and 8½x. (See Tables 5 and 6.)

Forty-five of the 81 subjects rated an S for reading and 39 rated an s for writing; 67 rated either an S or M for reading and 56 rated an s or m for writing. This is very

Table 7

READING RATES ACHIEVED BY SUBJECTS

Reading Rate (wpm)	No. of Subjects
0 to 2	14
3 to 10	1
11 to 20	6
21 to 30	6
(a)	9
31 to 39	13
40 to 49	4
50 to 59	8
60 to 69	6
70 to 79	5
80 to 89	1
90 to 99	3
100 to 109	1
110 to 119	2
120 to 190	2
Total	81

[a]The subjects represented in this line of the table rated an M for reading, but the exact rate at which they read could not be determined. It ranged between 3 and 30 wpm. This was due to one of several causes: the subjects were either too nervous to perform consistently, or they tired easily, or they showed marked signs of senility.

encouraging, because the subjects reached this level of achievement with no more than 30 minutes of actual experience with RANDSIGHT I. Genensky's experience with CCTV systems indicates that most partially sighted people who initially read 30 or more words per minute can easily expect that over time they will at least double their reading rate.[4] This observation appears to be supported by the experience of some of our subjects; for example, after reading between 5 and about 20 minutes, subject number 49, using newspaper column type, increased his reading rate from 50 to 90 wpm, and subjects 60 and 69, using double-spaced typewritten

[4] This may not be true of persons who initially read at relatively high reading rates, say, in excess of 150 words per minute. There may be an upper limit at which a person can read with the aid of a CCTV system, which is set by the CCTV system itself and not by an inherent limitation of viewer ability. Edwin Mehr, O.D., of the University of California at Berkeley, suggested this possibility to us.

Table 8

SUBJECTS' WORKING DISTANCES FROM MONITOR SCREEN

Working Distance (in.)	No. of Subjects	
	Reading	Writing
1 to 2½	4	3
3 to 4½	13	19
5 to 6½	30	18
7 to 8½	14	8
9 to 10½	4	3
11 to 12½	8	2
13 to 14½	3	--
15 to 16½	2	1
17 to 18	1	1
Unknown	2	26
Total	81	81

material, increased their reading rates from 25 to 40 to 60 wpm and from 37 to 45 to 65 wpm, respectively. It is also interesting to note that of the 22 subjects who rated an M for reading, at least 10 read between 20 and 30 words per minute. It is likely that persons who can read as few as 20 words per minute can also expect to double their reading rate with time.

It is important to recall that all our reading rate measurements were made with the subject reading aloud. Therefore, it is not unreasonable to assume that the reading rates of some subjects, particularly those who read, say, 50 or more words per minute, would have been higher had they read to themselves. However, for very slow readers, especially those who had difficulty putting individual letters, syllables, or words together, we conjecture that their reading rates would not have changed appreciably had they read to themselves.

Another factor that may have limited some of our subjects in their reading or writing performance is that we use only 9-in. monitors. Conversations with persons involved in the manufacture and sale of CCTV systems indicate that the vast majority of their customers prefer to use much larger monitors. It is therefore possible that some of our subjects were inhibited by our 9-in. monitors and would have performed better if they could have used, say, a 12-, 15-, or 17-in. monitor.

Although Tables 2 through 8 do not record subject preference for contrast reversal, our records show that over 60 percent of the subjects, when viewing ordinary reading and writing materials, definitely preferred viewing a negative image to a positive one.

VI. ELECTRONIC IMAGE ENHANCEMENT

One of the major advantages of CCTV systems for the partially sighted is the ability to manipulate the electronic signals representing the image. By this means, we can actually improve the contrast over that available in the original material; in fact, the contrast can even be reversed from black on white to white on black, if desired. Extraneous material can be eliminated by appropriate electronics, giving the viewer a wide range of control of image characteristics. In this section, we discuss the various electronic techniques that we have explored; electronic circuit details are provided in the related appendices.

CONTRAST REVERSAL

One of the first areas we explored further in this project was contrast reversal, namely, the ability to electronically reverse the order of the gray scale.[1] With contrast reversal, the image on a TV monitor of black type on a white background appears as white type on a black background. This is particularly valuable to partially sighted people who are bothered by scattered light, for example, persons who have scarring of the cornea, lens opacities, or light-scattering material floating in either the anterior or posterior chambers of the eye. The value of contrast reversal is particularly striking for some partially sighted people who are photophobic, for normally they find reading and writing almost impossible. When they use a closed circuit TV system equipped with contrast reversal, they are able to carry out these operations in relative comfort. When subjects were asked whether they preferred to view a positive or negative image of reading and writing materials, about 60 percent of them stated that they preferred the negative image. This is not surprising, because most printed and handwritten material consists of dark symbols on a light background, and the area occupied by the symbols is significantly less than that

[1] Research on contrast reversal was begun before the start of our SRS grant (see Ref. 5); it was continued under that grant, but until now we have not published the details of how contrast reversal was actually introduced into our Shibaden monitors.

occupied by the background. Thus, when such materials are viewed with a closed circuit TV system with normal contrast, the light entering the eye comes from the background and not from the symbols—but it is the symbols that carry most of the useful information.[2] While the bright background may be distressing in itself, to persons who are bothered by light scattering, some of the scattered light from the background will fall in the dark areas containing the information and thus will reduce image contrast and make reading and writing even more difficult.

When the contrast is reversed, ideally no light comes to the eye from the background and the only bright objects in the field of view are the symbols that convey most of the available information. The total amount of light reaching the eye is smaller than when contrast reversal is not used and is now more in harmony with the available information than before. This reduction in the total amount of light required to read or write is a distinct advantage for photophobics. Further, if the viewer's eye tends to scatter light, with contrast reversal there is usually less light to be scattered and thus the reduction of contrast should be less.

Our experience has shown that partially sighted people who suffer from light scattering within their eyes can read and write significantly longer when viewing a negative or reversed contrast image than when viewing a positive image. Genensky reports that when he views a positive image, he is obliged to rest his eyes after 15 to 30 minutes of reading or writing. However, when he uses reverse contrast, he is able to carry on these operations for hours without taking a break.

Based on our experience, we strongly believe that any electro-optical system designed to aid the partially sighted to read or write should have the capability to provide an image with reversed contrast.

CONTRAST ENHANCEMENT

Another desirable capability that electro-optical systems permit is enhancement of contrast over what is available in the source material. When reading or writing, one is usually not concerned with shades of gray but only with black and white (ignoring personal aesthetic preferences, for example, for green ink on yellow paper). This is particularly true for the partially sighted who, as a rule, need as much contrast as they can obtain.

One way to accomplish high contrast electronically is to pass the video signal through a threshold detector, which provides full output if the video signal is at any level above the threshold and no output for any video signal below the threshold level. This supplies an output with a two-step gray scale, and the monitor controls can be set to make these values correspond to high brightness and complete blackness, respectively, or vice versa if contrast reversal is used. By providing a control that varies the threshold value, the viewer can detect a range of contrast values in the material being viewed.

[2] The background does contain some information; for example, it provides the viewer with data regarding the spacing between lines, words, and sentences.

A major disadvantage of this approach becomes especially apparent when working under low illumination conditions or with low contrast source material, such as a newspaper. Noise, which is always present in the video signal, varies with time and can trigger the threshold device off or on near the edge of the character. The normally stationary edge of a character will seem to jump from side to side in a random fashion. Further, small spots in the background will turn off and on as the noise carries the video signal above and below the threshold, creating a scintillating effect that is most annoying.

These problems can be avoided by modifying the threshold device to produce a nonlinear gray scale rather than off-on (two-step gray scale) in the vicinity of the threshold. For example, if the video signal varies from zero to one volt, we might arrange to have a zero output until the input reaches .3 v, a linearly varying output ranging between zero and one volt when the input varies between .3 and .7 v, and an output of one volt for any input over .7 v. In this case, a typical noise signal of about .1 v will cause only one-fourth as much maximum output variation as the two-step gray scale might. Another advantage of this approach over the two-step gray scale is that it can provide some compensation for variations in sensitivity over the face of the vidicon.

In addition to the effects of noise, the use of randomly interlaced scanning in the TV camera causes a noticeable and annoying ripple in characters when displayed on the screen with a high contrast image. This can be totally eliminated by using a fixed 2:1 interlace, so that each horizontal scan line starts at the same vertical position on the screen rather than at a random location within a short distance from its nominal location. However, 2:1 interlace cameras are more expensive than random interlace cameras. Any monitor will work with either system, and although the apparent ripple can be reduced by simply decreasing the contrast, this would reduce the advantage of contrast enhancement and thus is not the solution to the problem.

ELECTRONIC WINDOW

Several early observations of subject confusion resulting in repeated loss of place while reading with RANDSIGHT I led to the incorporation and occasional use of what we call an electronic window. To some extent, the electronic window can be viewed as a kind of "typoscope." The typoscope is a visual aid consisting of a rectangular piece of black cardboard with a rectangular slit usually centered and running almost its entire length. When the typoscope is placed on a printed page, only one or two lines can be seen through the slit. Since we work with a range of magnifications, we provided the electronic equivalent of the typoscope with control over the window (or the slit) height and location as viewed on the monitor screen. Figure 10 demonstrates the electronic window in use.

With only a limited amount of testing, a few tentative conclusions may be drawn about the electronic window:

1. Even with an electronic window, reverse contrast will probably be preferred by the partially sighted to normal contrast.
2. If the window is set for a single line, it is fairly easy to lose track of what line the viewer is on, whether normal or reverse contrast is used.
3. As a consequence of statement 2, viewers will probably prefer to set the window height so as to encompass two or three lines rather than one.
4. There is apparently some advantage in using a fairly high window, which cuts off the very top and bottom of the monitor image. One reason for this is that contrast is often poorest in those areas of the image; another reason is that there may be extraneous lines visible in those areas that are due to some of the vertical synchronizing effects.
5. Normally, blanking is turned off and on very quickly—typically in a fraction of a microsecond. This leads to a very sharp edge at the top and bottom of the window. When bright elements of the image occur at this sharp edge, they appear to turn off and on in an annoying manner. Although this effect is much worse with a camera having a random horizontal sync, it is not completely eliminated even with a 2:1 interlace. A simple solution to this problem was found—and one that was dramatically effective—which we call a "soft window." We slowed up the turn-off and turn-on of the window so that these transitions occurred over several horizontal scan lines.

Appendix C describes what modifications were made in the Shibaden monitors to achieve contrast reversal and to create an electronic window.

VIDEO INFORMATION PROCESSOR

Our experience with contrast reversal, contrast enhancement, and the electronic window convinced us that it would be desirable to have a "black box," inserted in the coaxial cable between the camera and the monitor, that could provide these functions without having to make modifications to either the camera or the monitor, which likely would result in a loss of warranty. The Video Information Processor (VIP) designed and fabricated in the course of this project is such a box. It permits the viewer to

1. Switch the polarity of the image displayed on the monitor screen (i.e., produce contrast reversal).
2. Introduce an electronic window into that image.
3. Manipulate image contrast and brightness beyond that available with only the use of the monitor controls.

VIP can be used with nearly any TV camera and any TV monitor.

Care was taken in designing VIP to ensure that it be as simple to operate as possible. One of its controls allows the viewer to provide contrast reversal; another

permits him to vary the level of contrast enhancement in either polarity; a third allows him to select either a full picture, or one in which a rectangular portion of the picture on the top, bottom, or on both the top and bottom of the screen is blanked out (i.e., it permits him to introduce an electronic window); a fourth control allows him to vary the height of the electronic window; and a fifth one permits him to change the vertical position of the window.

In the design of VIP, we also attempted to minimize the number of parts required and to choose minimum cost components. Unfortunately, relative to cost, our findings were rather disappointing. For example, if one were to build the power supply and the rest of the necessary circuitry oneself, the cost of the components would run approximately $35.

Because constructing a VIP is not a job for an amateur, we have made several attempts, unfortunately unsuccessful, to interest electronic manufacturers in the VIP concept, in the hope that they would add instruments based on that concept to their product line. This would give those who are not skilled in electronics and who wish to assemble their own CCTV system an opportunity to include in their instrument the electronic features that are available with VIP and that we have found so useful.

One of the major objectives of VIP is to permit the viewers to use moderately priced cameras and monitors and to obtain the same image quality and flexibility that can be had with expensive cameras and monitors together with specially designed circuitry. Although we went a long way toward achieving this goal, we were not able to include the production of an image of uniform quality over the entire monitor screen as part of the VIP package.[3]

One of the major problems we encountered in our VIP research was the variability of operating characteristics from camera to camera, even in the case of cameras produced by the same manufacturer and bearing the same model number. The most deleterious variation we encountered was that of sensitivity at different positions in the field of view; for example, one camera might have reasonably uniform sensitivity over the field, while another of the same make and model might exhibit variation as much as two to one over the same field. In the latter case, the image contrast would vary by the same amount, making contrast enhancement very difficult. Thus, with a good camera, contrast enhancement can provide a dramatic improvement in image quality—nearly equivalent to that obtainable with a lightbox (see Sec. VII). However, with a poor camera, the improvement is marginal.

Another problem we encountered involved the video signal characteristics. The signal level, sync amplitude, sync width, etc. seem to vary from model to model, so that in going from one model to another, the VIP needs to be readjusted. Although it might be possible to make this adjustment without an oscilloscope, the use of such a device makes the job much easier.

Appendix D describes the circuit details of our Video Information Processor.

[3] By the production of an image of uniform quality over the entire monitor screen, we mean eliminating bright and dark areas from the image that are present even when the TV camera is viewing a diffuse surface that is uniformly illuminated.

VII. LIGHTBOX TEST

We have developed an inexpensive test, which can be administered by an ophthalmologist, optometrist, or other qualified person, to determine whether a closed circuit TV system could assist a partially sighted person to read printed and handwritten material. We recognize that no test that does not involve the actual use of a CCTV system will be completely satisfactory. Nevertheless, we feel confident that we have devised a test that will permit the practitioner to predict with reasonable certainty whether a partially sighted person could benefit from such an instrument.

The test is very simple and can be administered rapidly. It consists of having the partially sighted person sit before a lightbox, such as that found in a physician's office for reading x-rays, and having the patient view a set of four positive and negative transparencies that display typewritten material magnified linearly 1, 2, 4, 8, or 16 times (see Figs. 12a and 12b). If the patient is able to read any of the displayed material, with or without the help of corrective lenses, there is a good chance that a CCTV system could benefit him. However, in those cases where the patient is obliged to piece words together, a letter or part of a letter at a time, the potential reading speed with a CCTV system may be too slow to warrant the purchase of such a device. Our experience has shown that most partially sighted persons who are not able to view at least three or four alphanumeric symbols at one time tend to read so slowly with a CCTV system that it is questionable whether such an instrument is appropriate for their use. *And yet even here one must not draw absolute conclusions,* for persons with the ability to see one or two letters at a time, and who are highly motivated, frequently are able to perform phenomenally well. For example, a young veteran who had been injured in the Vietnam conflict could resolve typewritten material magnified linearly two times at a distance of 16 in. However, at that magnification and distance, he could only see, at one time, a single letter, not the next letter, and the following one and a half letters. Even so, he was able to read at the rate of 35 words per minute, with about 5 minutes' experience with RANDSIGHT I. This young man displayed exceptional determination in so effectively utilizing the very small and divided visual field that remained to him.

We have generally administered our lightbox test in a room with subdued lighting. However, for most partially sighted people, this is probably not necessary, as they will perform about equally well with normal lighting. This has been the case

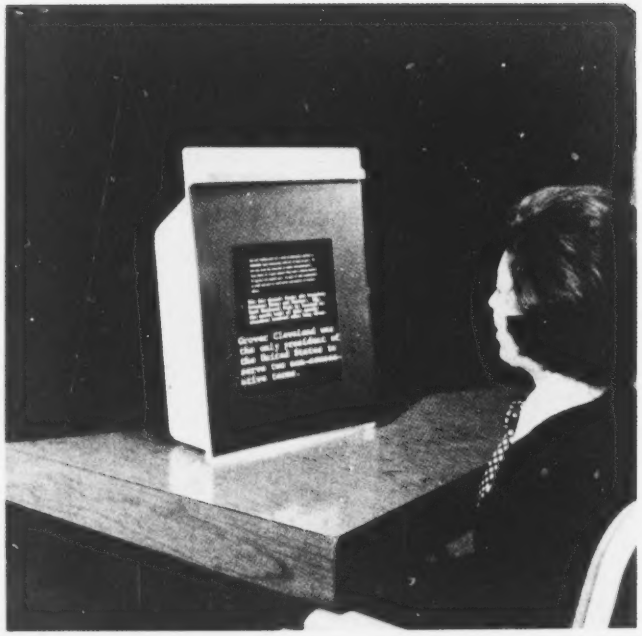

Fig. 12a—Subject viewing a negative transparency on the lightbox; type shown (from top to bottom) is magnified 1x, 2x, and 4x, respectively

Fig. 12b—Subject viewing a positive transparency on the lightbox; type shown (from top to bottom) is magnified 8x and 16x, respectively

with respect to the use of our RANDSIGHT equipment. However, this is not true of partially sighted people who are very light sensitive. These people perform much better with subdued room lighting or with no room lighting at all Two of our subjects were so light sensitive that any extraneous light tended to inhibit their use of RANDSIGHT II.[1] Fortunately, such extreme cases of light sensitivity appear to be rare. In view of the above, it would probably be advisable to administer the lightbox test with subdued room lighting; this would eliminate most of the complications that arise when dealing with subjects who tend to be light sensitive.

The screening test can also be used to determine roughly what linear magnification a patient prefers and how close to the monitor screen he will have to be to read at that magnification. Because the viewing conditions on the test display surface are not identical with those encountered when viewing a TV monitor, the parameters measured with the test display may differ slightly from those encountered when viewing the monitor screen of a CCTV system. This follows from the fact that the test materials consist of high-contrast, black-and-white, positive and negative photographic transparencies set in opaque black cardboard frames, which have the same dimensions as the ground-glass face of the lightbox. Hence, when the test materials are viewed with the full illuminating capability of the lightbox, they exhibit brightness and contrast that, in general, although not identical, are comparable with that found when viewing some of the bright, high-contrast CCTV equipment currently available. If the image on a TV monitor has less contrast and/or is not as bright as that on the test display, then, when using that monitor, a viewer will probably need greater effective magnification than that predicted by the screening test.

Effective magnification is defined to be 16 times the linear magnification at which a viewer is able to resolve an object, divided by the distance, measured in inches, between the object and his eyes. This is a rough indicator of how many more times an object must be magnified on a partially sighted person's retina than on a normally sighted person's retina before it is resolvable. *Both* the linear magnification of the object *and* the viewer's proximity to the image of that object are accounted for. If the viewer, for example, finds that he can resolve pica type having a linear magnification of 9x with his eyes 2 in. from the magnified image of the copy, we say that he needs an effective magnification of 72x to read the material.

The test display demonstrates dramatically to even the normally sighted why so many partially sighted people prefer a negative image to a positive one when viewing dark type on a light background (see Figs. 12a and 12b). The eye, normal or pathological, tends to fatigue more rapidly when viewing a large display that consists of dark letters occupying a small area in a very light background, than it does when it views the same display with the dark and light areas interchanged. In the latter case, as pointed out in the previous section, the only bright objects in the scene are the letters themselves, and they are the objects in the field that convey most of the useful information. Viewing a negative image is especially useful for persons who have corneal scarring, cataracts, or light-scattering material floating in either the aqueous or vitreous humor.

[1] Subsequent to the visit of these subjects, we have made the room housing RANDSIGHT II almost lightproof.

VIII. SOME CRITERIA FOR CLOSED CIRCUIT TV SYSTEMS FOR THE PARTIALLY SIGHTED

We are often asked to state the criteria that we believe must be met if a closed circuit TV system for reading or writing is to be of value to the partially sighted. This is not easy to do, because advances in electro-optical research, as well as innovations in mechanical and electro-optical design, can and do make it necessary to alter the criteria. Thus, the criteria of today may not be the appropriate criteria of tomorrow. In the list we have assembled below, the criteria whose descriptions include the word "must" are those that we currently believe are essential to the design of closed circuit TV systems if they are to be of lasting value to the partially sighted. The other criteria are less important but should be incorporated in instrument designs whenever possible.

GENERAL CRITERIA

1. All the parts of the instrument must be of high quality, including its frame, lens system, camera, monitor(s), illuminator, and X-Y Platform. The instrument must be rationally designed and well constructed. Much of what follows amplifies what we mean by "rationally designed and well constructed."
2. All controls must be located so that they are readily accessible and easy to operate by the viewer.
3. The TV monitor must be located at a convenient height above the supporting desk or table and at a distance and attitude that allow a viewer to see the monitor screen without holding his head at an uncomfortable angle or in an unnatural position. Because the height and visual characteristics of viewers will vary, adequate provision must be made to adjust the position of the TV monitor to ensure viewer comfort.
4. The optical height of the TV camera above the upper surface of the X-Y Platform must be adjustable over a range of at least 4 in. The lower face of any structure (e.g., the TV-camera zoom-lens assembly) must not be closer than 8 in.

(preferably 9 or 10 in.) from the upper surface of the X-Y Platform when the CCTV system is in use.

5. Capability must be provided to present a normally oriented image on the TV screen even when the viewer chooses to rotate the X-Y Platform, in order, for example, to write more comfortably.

6. The entire CCTV system must be wired so as to permit the viewer to turn it on and off by means of a single, conveniently located switch.

7. The mechanisms for adjusting the location of the TV camera and the TV monitor must provide positive control of position at all times (i.e., the monitor should not be able to drop while attempting to change its position).

8. The TV camera mounting must be rigid, and it must not permit camera vibration that degrades image quality on the TV monitor.

9. It might be desirable for the illuminator and the zoom-lens system to be capable of accommodating one or more filters.

TV CAMERA AND TV MONITOR CRITERIA

1. Either the TV camera, the TV monitor, or a "black box"[1] connected between the TV camera and the TV monitor must be capable of producing an image on the TV monitor screen that has either a normal or a reversed gray scale. The viewer must be able to reverse the gray scale, or more technically produce contrast reversal, by simply flipping a switch or turning a knob.

2. The image produced on the TV monitor screen by the TV monitor, TV camera, and zoom lens, regarded as a single system, must be in focus over the entire screen and must be free from visible noise. The geometric distortion of this system must not exceed 4 percent.

3. The TV camera, TV monitor, illuminator, and any other pieces of equipment that draw electricity must be electrically grounded through their AC power cords.

4. The TV camera and the TV monitor must be adjusted so that the contrast and brightness controls on the TV monitor change those parameters over a useful range.

5. Image enhancement greater than that produced by a fast high-quality lens, coupled with a nonmodified TV camera and TV monitor, is desirable. This can be accomplished by increasing the amplification of the signal generated in the camera or by modifying the gamma of the system.

6. It is desirable to have uniform brightness over the entire monitor screen under various settings of the TV monitor's brightness control when the TV camera is viewing a surface that is illuminated uniformly.

7. Image stability must be controllable by merely adjusting the vertical and horizontal controls on the TV monitor, and once these adjustments are made the image should remain stable under normal working conditions.

[1] For example, the Video Information Processor described in Sec. VI.

8. A capability of producing vertical electronic blanking, that is, an electronic window, may be desirable, and can be useful in conjunction with a normal or reversed image. To avoid the appearance of wandering bars on the top and bottom of the window due to random sync, the window should turn off and on slowly, that is, during the time it takes to sweep over several horizontal lines.

9. The TV monitor must be equipped with an effective implosion shield.

10. The zoom lens, TV camera, and illuminator should all have sufficient field uniformity to provide an image all of whose elements are of similar brightness and contrast on the TV monitor.

11. When the TV camera is viewing well-illuminated, high-contrast material, the brightness available on the TV monitor should be so intense that it causes, or almost causes, visual discomfort to a normal eye, when located close enough to the monitor screen that its visual field is almost completely filled with the image of that screen. Under the same illuminating conditions, the contrast on the screen should be such that dark portions of the image are the result of almost no visible output being produced in those areas by the monitor circuitry.

12. The TV camera must have a resolution of at least 300 lines across the field of view.

13. The TV monitor acceleration voltage probably should not exceed 19 kv.

14. The TV camera must be capable of producing a quality image on at least two monitors simultaneously.

15. It is desirable that a camera employing a 2:1 fixed interlace be used to avoid the annoying ripple effect that occurs in high-contrast portions of an image.

16. It is desirable that the TV camera have both RF and video output capability so that a TV receiver can be used should the TV monitor need repair.

17. It is desirable that a TV monitor be used rather than a TV receiver for two reasons: (1) The RF output from the camera to a TV receiver is generally of lower bandwidth than the video output to a monitor, and (2) many TV receivers cannot utilize a wide bandwidth signal even if available.

CRITERIA FOR THE ILLUMINATOR

1. The illuminator must provide light that is constrained as closely as possible to cover only the maximum field of view of the camera-lens system (when the lens is set at minimum magnification).

2. The light produced by the illuminator on the upper surface of the X-Y Platform must be of uniform intensity, in the sense that when the CCTV system is viewing a page of uniform quality, the illumination must not introduce variations in image brightness and contrast that are not inherent in the material being televised.

3. The illuminator must be located so that when the viewer is writing with the CCTV system, the shadow of his hand and of his writing instrument does not interfere with his writing.

4. The illuminator must be properly shielded to eliminate the possibility of the viewer being burned by touching or grasping it during day-to-day use of the CCTV system.

5. The illuminator should probably be equipped with a mechanism that permits the viewer to vary the brightness of the spot of light it produces.

6. The illuminator must be shielded to eliminate the possibility of stray light passing out through its sides or top into the eyes of the viewer. Further, direct view of the bright surfaces of the illuminator should not be possible; nor should it be possible for the illuminator to shine directly into the eyes of the viewer under normal working conditions.

7. The illuminator must be located so as to prevent direct reflection into the eyes of the viewer when it is lighting a highly reflective surface, such as a sheet of paper with a glossy finish.

8. A sturdy but easily manipulated mechanism to control the location of the illuminated area must be provided.

9. It is desirable that the illuminator design be such that it accepts bulbs that are readily obtainable and easily changed.

CRITERIA FOR THE ZOOM-LENS SYSTEM

Either a high-quality fixed focal length lens with a bellows extender or a zoom lens should be used. Once focused, a zoom lens will produce changes in magnification over its zooming range by a simple turn of its zooming sleeve. However, in most cases, a zoom lens will not produce the highest possible quality image over its entire zooming range. A fixed focal length lens with a bellows extender, once focused, will generally produce a higher quality image, but to change magnification with such a lens, the extension of the bellows must be altered *and* the entire lens and TV camera raised or lowered until focusing is achieved. Our experience has shown that unless a very highly magnified, sharp, high-contrast image is needed, it is preferable to use a zoom lens, because with such a lens-changing magnification (over its zooming range), it is much more convenient, less complicated, and faster than a fixed focal length lens-bellows extender combination.

1. The zoom lens must provide at least a 4 to 1 range of linear magnification of an object located on the X-Y Platform; it must do this in such a way that the image seen on the TV monitor screen remains in focus throughout the entire zoom range, and the distance between the zoom-lens system and the object remains constant once the zoom lens has been initially focused. This may require adjustment of the vidicon position to match the designed mounting distance of the lens being used.

2. The zoom lens should be of high enough quality to produce an image on the monitor screen that is free from noticeable pincushion, barrel, or other distortion, and it should be fast enough to be used with ordinary room lighting or with a light source provided as part of the CCTV system.

3. The zoom lens probably will need to be equipped with one or more close-up

lenses in order that it can be focused at a working distance of 8 to 12 in. from the material on the X-Y Platform and produce an image on the TV monitor that lies within a usable magnification range. The usable magnification range will vary from viewer to viewer, but most viewers (probably better than 90 percent) will require linear magnifications on the monitor screen that are no less than 1 and no greater than 20. Further, each viewer will need to cover only a fraction of that range; for example, one viewer may need to see material magnified between 1.5 and 6 times and another 4 to 16 times in order to cope with nearly all the reading and writing materials they may expect to encounter.

4. The zoom lens may need an extender placed between it and the TV camera to change the range of magnification without appreciably changing the distance of the lens from the material being viewed.

CRITERIA FOR THE X-Y PLATFORM

Closed circuit TV systems for the partially sighted that involve the use of an X-Y Platform, such as the one described in Sec. IV, are simpler, less costly, and more effective than many other more complicated instruments.[2] They are also vastly superior to devices that require a viewer to maneuver reading or writing materials along a desk or table surface with his hands.

1. The X-Y Platform must be sturdily constructed with smooth running guides that allow unobstructed motion of its upper surface at least 8 in. in the x-direction and 11 in. in the y-direction under loads as light as a sheet of typing paper or as heavy as an unabridged dictionary.

2. The platform's nonmoving parts must be sufficiently massive, and the bottom face of its base must be equipped with friction pads or otherwise constrained, to prevent these parts from slipping or sliding on the supporting desk or table while its loaded upper surface is being manipulated. It should be noted that viewers generally prefer to operate an X-Y Platform whose parts, both moving and stationary, are rather massive.

3. The platform must have a braking mechanism that permits easy and convenient adjustment of the ease with which its upper surface moves in the y-direction, without appreciably altering the smoothness with which it moves in either the x- or the y-direction.

4. The platform must not have sharp edges or corners that could cause injury to a viewer.

5. The platform must have an upper surface that measures at least 12 in. in the x-direction and 12 in. in the y-direction, but the upper surface must not be so large, or have so much traverse, in either the x- or y-direction that it (1) runs into the viewer or another part of the CCTV system, or (2) causes the entire platform to become unstable when it is being manipulated. It should be noted that the platform's

[2] For example, RANDSIGHT I as described in Ref. 2.

upper surface need not be square; some viewers may prefer that the surface be wider than it is long or vice versa.

6. The exposed face of the platform's upper surface must be finished so as to eliminate or greatly reduce glare, to allow easy manipulation of reading and writing materials, and to create enough contrast on the TV monitor screen that the reading and writing materials can be easily distinguished from the platform surface.

7. Height of the platform should be kept to a minimum. It must not exceed 3 in. above the supporting desk or table and preferably be less than 3 in.

8. It is desirable for the platform to have a grid or other markings painted on the exposed face of its upper surface to serve as guides for the viewer to center and align the platform relative to the TV camera and its optical system and to center and align reading and writing materials when they are placed on the platform's upper surface.

9. The force needed to move the platform's upper surface in the x-direction should be of the order of a few ounces, and that needed to move it in the y-direction should be adjustable and in most cases should not exceed a few pounds.

IX. OTHER RESEARCH ON CLOSED CIRCUIT TV SYSTEMS FOR THE PARTIALLY SIGHTED

In 1959, A. M. Potts, D. Volk, and S. W. West [10] described a closed circuit TV reading device that consisted of a Dage CCTV camera equipped with a 3-in. telephoto lens and a 14-in. monitor. Reading material was clipped to a stand, which could be moved by means of a manual gear drive in any direction over a horizontal plane. The TV camera was fixed in space, and the instrument produced a linear magnification of 10x on the 14-in. monitor.

In 1968, C. A. Weed [11] described a CCTV reading instrument that employed a hand-held TV camera that was moved across the page to scan the printed word. In correspondence with Weed, dated March 26, 1968, Genensky learned that Weed and his colleagues had modified their reading device. The letter states that now "the camera is held stationary above the desk, and the printed page is moved beneath the lens by means of a mechanical stage."

As of 1970 Weed [12] described a CCTV system that incorporates a 19-in. Shibaden TU-19UL monitor and a Shibaden HV-50 or HU-14 camera. Magnification changes are made by adding or subtracting extension tubes between the fixed focal length lens and the camera. Illumination is supplied by a 60-w gooseneck desk light or by a Tensor desk lamp. Reading materials are moved completely by hand on a table below the down-pointing camera. In the tests, which were carried out with 14 subjects, this CCTV system was compared with two optical magnifiers. This comparison is of dubious value, because the subjects were constrained to view an image with a fixed magnification of 10x at a fixed distance (40 cm) from the TV monitor. Thus, Weed was assuming that all his subjects could use a CCTV system at one and the same *effective magnification*, namely, 10x. As pointed out in Sec. V, Table 6, this is an unjustified assumption.

In 1968, S. M. Genensky, P. Baran, H. L. Moshin, and H. Steingold [2] described a CCTV reading and writing system (RANDSIGHT I), which at that time consisted of a Concord MTC-12 camera that translated vertically by means of a motorized control to accomplish focusing of a variable focal length lens and that rotated about a horizontal axis to carry out scanning of the printed or handwritten line. The camera rotation was governed by a hand-operated servomechanism. A 5-in. Sony

television receiver, Model 5-307UW, rested on a shelf that could be moved up or down slightly and toward or away from the viewer to suit his convenience. Additional information concerning this early instrument is contained in Refs. 3 and 4.

Currently, RANDSIGHT I is equipped with a Shibaden HV-15S camera, two 9-in. Shibaden MV-903 monitors, and a Canon TV zoom lens V6X16 equipped with a plus 4 add. The camera no longer rotates about a horizontal axis, and the entire servomechanism control has been removed. The camera can still be raised and lowered by a motorized control, and it can now be rotated manually about its optical axis.

Reading and writing materials are now placed on an X-Y Platform and easily maneuvered below a stationary camera to carry out line scanning and shifting from line to line.

Contrast reversal is produced at each monitor by flipping a switch, and an electronic window is introduced and varied in position and height by the turn of two control knobs. (See Refs. 5 and 6.)

In 1969, J. H. Kuck sent us a manuscript of a paper entitled "How To Build a Closed Circuit TV Reading Aid" [13]. In his instrument, the TV camera (Ampex CC-6007) is mounted vertically and can be moved in two orthogonal directions in a plane parallel to the working surface by means of a set of cranks. The reading material is set in a "tray," which can be shifted by means of a lever from left to right through a distance of 2.5 in. A 20-in. TV monitor (Setchel-Carlson 2100-SD) is used, and changes in magnification are made by raising or lowering the camera and refocusing its lens system.

In a letter dated March 12, 1971, we learned that H. L. Jonkers and his colleagues at the Delft University of Technology, Delft, Netherlands, have been carrying on research since 1968 on a CCTV instrument for the partially sighted.

Jonkers reports that their experimental equipment uses a CCTV system produced by "Fernsch GMBH Darmstadt." The camera operates at 60 fields per second (interlaced) and 735 lines per frame, and the monitor screen has approximately a 60-cm diagonal. The camera is equipped with a "variable focal length objective," and the linear magnification of the image on the monitor screen may be as large as 24x. At the time the letter was written, the instrument used a servomechanism to produce x-y image scanning. However, research was in progress on an "electronic image scanning mechanism."

In a letter dated February 5, 1971, to Genensky, we learned that A. Torvi and his colleagues at the University of Calgary, Calgary, Alberta, have also been experimenting with CCTV systems for the partially sighted since 1967. One of their devices is an instrument for scanning a chalkboard, and the other is a device for reading printed and handwritten material. In an attachment to Torvi's February 5, 1971, letter, and from a copy of a progress report that accompanied his September 20, 1971, letter, we learned that the "blackboard viewer" consists of a TV camera mounted on the equivalent of a tripod head and a 16-in. monitor that sits on a shelf or desk. The camera can be raised or lowered and rotated so as to be placed in the most convenient position to view a distant area of interest. As currently configured,

this instrument, including its supporting desk or stand, can be wheeled as one unit from classroom to classroom.

The reading instrument is not described in detail, but from the available photograph we *infer* that it consists of a large monitor and a down-pointing camera that views printed matter placed on a movable stand, which from the photograph appears to be moved toward or away from the viewer (rather than from left to right) to scan a line and from side to side to shift from line to line.

P. McGoldrick [14] and his colleagues at the Lawrence Livermore Laboratory in Livermore, California, designed a CCTV system that departs quite sharply from conventional designs. It consists of a hand-held camera and a monitor unit. The monitor unit includes the video processor circuits and power supplies. In addition to the normal controls on ordinary TV systems, this device offers the following switchable choices: a normal gray scale, an inverted (or reversed) gray scale, an inverted two-step gray scale, and adjustable horizontal blanking. The hand-held camera looks like an ordinary flashlight and when in operation is held in a vertical position (flared end downward) and rests directly against the material to be read. Line scanning is accomplished by moving the camera by hand across the printed line. The instrument, including its carrying case, weighs 28 lb (the carrying case alone weighs 12 lb, but as pointed out by McGoldrick could be reduced to a few pounds).

Our SRS/Rand-sponsored research was the inspiration for the research carried on by McGoldrick and his colleagues. Throughout the course of designing their instrument, we provided them with advice and encouragement, and when asked, we reviewed their work.

M. Lavieri and G. B. Wilson [15] of the University of California at Berkeley, California, have designed and built a "portable" CCTV system that may be used for reading and writing. A Sony SVC 2100A camera and a Sony 5-in. receiver were modified and placed in a rectangular wooden housing, which stands on four legs. The axis of the camera lens is horizontal, and the lens projects through the right side of the housing. A mirror is used to bring the image of the printed page to the lens. The reading and writing material is placed on a rectangular platform, which may be moved in both the x- and y-directions. When Genensky saw the instrument in the summer of 1971, the reading material was moved toward or away from the viewer, rather than from left to right, to achieve line scanning, and it appeared to operate at a linear magnification of 9x. The contrast is reversible, and the entire instrument, including the platform, weighs 30 lb. It is not clear how this instrument is used for writing.

REFERENCES

1. Genensky, S. M., *A Functional Classification System of the Visually Impaired To Replace the Legal Definition of Blindness*, The Rand Corporation, RM-6246-RC, April 1970. Also published in *Annals of Ophthalmology*, Vol. 3, No. 2, February 1971, pp. 150-154; and *American Journal of Optometry and Archives of American Academy of Optometry*, Vol. 48, No. 8, August 1971, pp. 631-642.
2. Genensky, S. M., P. Baran, H. L. Moshin, and H. Steingold, *A Closed Circuit TV System for the Visually Handicapped*, The Rand Corporation, RM-5672-RC, August 1968. Also published in *Research Bulletin of the American Foundation for the Blind*, No. 19, June 1969, pp. 191-204.
3. Genensky, S. M., *Some Comments on a Closed Circuit TV System for the Visually Handicapped*, The Rand Corporation, P-3984, December 1968. Also published in *The Optometric Weekly*, Vol. 60, No. 14, April 3, 1969; *American Journal of Optometry and Archives of American Academy of Optometry*, Vol. 46, No. 7, July 1969, pp. 519-524; and Hearing before the Subcommittee on Education of the Committee on Labor and Public Welfare, U.S. Senate, 91st Cong., 1st Sess., on S.1611 to amend Public Law 85-905 to provide for a National Center on Educational Media and materials for the handicapped and for other purposes, April 23, 1969, pp. 45-48.
4. Genensky, S. M., H. L. Moshin, and H. Steingold, *A Closed Circuit TV System for the Visually Handicapped and Prospects for Future Research*, The Rand Corporation, P-4147, July 1969. Also published in *Annals of Ophthalmology*, Vol. 2, No. 3, June 1970, pp. 303-308.
5. Genensky, S. M., *Closed Circuit TV and the Education of the Partially Sighted*, The Rand Corporation, P-4343, March 1970. Also published in *Educational Technology*, Vol. 10, No. 8, August 1970, pp. 27-31.
6. Clewett, R. W., S. M. Genensky, and H. E. Petersen, *An X-Y Platform for RANDSIGHT-Type Instruments*, The Rand Corporation, R-831-HEW/RC, August 1971.
7. Trouern-Trend, Kenneth, *Blindness in the United States*, Report No. 7635-316, The Travelers Research Center Inc., Hartford, Conn., November 1968.
8. Bier, Norman, *Correction in Subnormal Vision*, Butterworths, London, 1960.

9. Boehm, George A. W., "Sam Genensky's Marvelous Seeing Machine," *The Reader's Digest*, January 1971, pp. 27-34.
10. Potts, A. M., D. Volk, and S. W. West, "A Television Reader," *American Journal of Ophthalmology*, Vol. 47, No. 4, April 1959.
11. Weed, C. A., "Electronic Image Enlargement for the Partially Sighted (A Description of Apparatus and Preliminary Results)," *Hartford Hospital Bulletin*, Vol. 23, No. 1, March 1968.
12. Weed, C. A., "Comparison of Television Reader for the Partially Sighted with Optical Reading Aids," *Hartford Hospital Bulletin*, Vol. 25, No. 3, September 1970, pp. 186-189.
13. Kuck, John H., "How To Build a Closed Circuit TV Reading Aid," *Research Bulletin*, No. 21, August 1970, pp. 49-76.
14. McGoldrick, P., *Visual Aid Closed-Circuit TV*, Lawrence Livermore Laboratory Report, UCRL-51160, December 17, 1971.
15. Lavieri, M., and G. B. Wilson, "A Portable Closed Circuit Television Aid for the Partially Sighted," *American Journal of Optometry and Archives of the American Academy of Optometry*, Vol. 49, No. 2, February 1972, pp. 178-179.

Appendix A
COPY OF SHEPHERD LETTER REPORTING ON X-RAY MEASUREMENTS

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December 2, 1970

Rand Corporation
1700 Main Street
Santa Monica, California

REPORT

MEASUREMENT OF X-RAYS ASSOCIATED WITH CLOSED CIRCUIT VIDEO MONITORS

The equipment checked was as follows:

1. Model VM-903 LA 10802 Ser. 090906. This unit was completely scanned on all six surfaces. The face of the monitor was scanned both with and without plastic sheet in place.

2. Model VM 903 RA 02039 Ser. 030562. This unit was completely scanned on all six surfaces.

3. Model VM 903 RA 02039 Ser. 030732. This unit was completely scanned on all six surfaces with the case removed.

4. Conrac Model CQF-9 Ser. 171362. This unit was completely scanned on all six surfaces.

5. Conrac Model CQF-21/875-60 Ser. 184778. This unit was completely scanned on all six surfaces.

6. Conrac Model CQE-17-875/945SP Ser. 99217. This unit was completely scanned on all six surfaces.

Instrumentation:

The instrumentation used to measure the emergent radiation from the above listed units was a J. L. Shepherd and Associates USM-1A rate meter, complete with SP-12 GM probe with window thickness of 1.4 mg/cm^2 and a window area of one square inch. The efficiency of the SP-12 probe is 2.5% as measured against a ^{55}Fe (5.9 Kev. photon energy standard manufactured by Isotope Products Laboratories, with calibration traceable to National Bureau of Standards.

Measurements:

All of the units surveyed had maximum net count rates (above background) of less than 80 counts per minute at the highest point.

82 counts per minute net (per square inch - the area of the detector - and a detector efficiency of 2.5%) represents a radiation field of 0.00017 mr/hr for 10 Kev X-Rays and 0.00032 mr/hr for 19 Kev X-rays.

Conclusion:

We can conclude that for the 10 Kev maximum voltage of the VM 903 units and the 19 Kev voltage of the Conrac series of monitors, external radiation levels were significantly less than 5% above normal background.

J. L. Shepherd
Health Physicist

JLS:cp

Appendix B

RANDSIGHT I

RANDSIGHT I, as it currently exists, consists primarily of two Shibaden (MV-903) TV monitors, a Shibaden (HV-15 or HV-15S) TV camera, a 6-to-1 Canon 16.5-95-mm zoom lens equipped with a plus 4 portrait lens, an Art Beam-Lite 75 illuminator, an X-Y Platform, and a supporting shelf.

The TV monitors are symmetrically placed on either side of the down-pointing camera and rest on shelves that are normally kept at a height of 11½ in. above the supporting shelf. They may be pulled toward or pushed away from the viewer over a distance of about 8 in. (from about 4 in. to 16 in. behind the front edge of the supporting shelf), and they may be raised or lowered slightly, although this is rarely done. Each monitor is equipped with circuitry and controls that permit it (1) to display an image with a normal or reversed gray scale, and (2) to vary the location and height of an electronic window on the monitor screen.

The TV camera can be moved up and down for focusing over a distance of 27 in. by means of a reversible motor and lead screw, and can also be rotated about its optical axis. The latter motion permits it to present an erect image of printed or handwritten material no matter what the orientation of that material is relative to the supporting shelf.

The zoom lens may be used with or without its 1.5x or 2x extenders. Without an extender, the image it and the camera produce on a 9-in. monitor has a linear magnification of between about 1x and 6x. If linear magnifications in excess of 12x are needed, the zoom lens is removed, and a fixed focal length lens with a bellows extender is used in its place. The latter can produce magnifications in excess of 30x.

The X-Y Platform rests on the supporting shelf below the camera and is used for reading and writing, as described in Sec. IV of this report. The supporting shelf is 60 in. long and 30 in. deep, and its upper surface is 29 in. above the floor.

This instrument is basically the one that was used throughout the informal testing program described in Sec. V. However, it did undergo some changes during the test period.

During January and part of February 1971, we operated the instrument with either room illumination only or with additional illumination provided by four

150-w dichroic spot lamps located about 3 ft above the supporting shelf and controlled by a dimmer switch. In mid-February 1971, we installed two Bausch & Lomb illuminators (Cat. No. 31-35-30) and worked with them until we installed the Art Beam-Lite 75 in June 1971. The illumination available from the Art Beam-Lite 75 is remarkably uniform, with a maximum effective intensity of 50 footcandles.

The camera mount in use throughout most of the test program did not permit rotation of the camera about its optical axis, but rather permitted limited rotation about another vertical axis. This had the effect of producing an erect image on a TV monitor for X-Y Platform orientations that favored right-handed persons, particularly with respect to writing.

At least one monitor was equipped with an electronic window in the spring of 1971, and at least one had contrast reversal capability before May 1970.

Figure 10 in Sec. IV shows RANDSIGHT I as it appeared in the early spring of 1971.

Appendix C

MONITOR ELECTRONICS

In our initial attempts to provide contrast reversal, we looked at the circuits of both the Shibaden HV-15 camera and the Shibaden MV-903 monitor. The easiest place to accomplish contrast reversal appeared to be at transistor Q7 in the Shibaden monitor. Initially, this transistor was used as a straightforward emitter-follower, with a voltage limit provided by the action of capacitor C-15 and resistor R-21 in the collector of this circuit. The initial circuit is shown in Fig. 13a. This was then modified by reconnecting C-15 through 470 ohms to the emitter of Q7 and changing the value of R-21 so that a signal of equal magnitude appeared at the collector as well as at the emitter of this transistor. The circuit now functions as a rather typical split-load phase inverter, in which a signal of opposite polarity to the input signal appears at the collector, and a signal of the same polarity appears at the emitter—points A and B, respectively, in Fig. 13b. By incorporating a switch that permits one to choose either point A or point B as the signal source for the following stage, one can obtain either reversed or normal contrast in the image seen on the television screen. This works fine for the normal video portion of the signal. However, during synchronization time, both horizontally and vertically, the signals that are normally at blanking or black level were inverted and appeared as an intense white level signal applied to the following stages. This caused a brightening of both horizontal and vertical retrace lines, which appeared as a fuzziness in the background during horizontal retrace and as a series of about seven or eight diagonal lines across the screen during vertical retrace time. This was eliminated by picking up appropriate signals elsewhere and applying them as additional blanking signals during contrast reversal.

An acceptable vertical blanking signal was found by observing that the emitter of transistor Q9 had a large positive signal during the vertical synchronization interval. This signal was coupled through the capacitor and resistor network, shown in Fig. 14a, in order to provide some control of the duration of the output pulse. For example, by increasing the value of the capacitor from .047 to .068 mfd, one could increase the length of the blanking pulse that appeared at the collector of transistor Q1. This signal was coupled through a 1000-ohm resistor to the collector of transistor

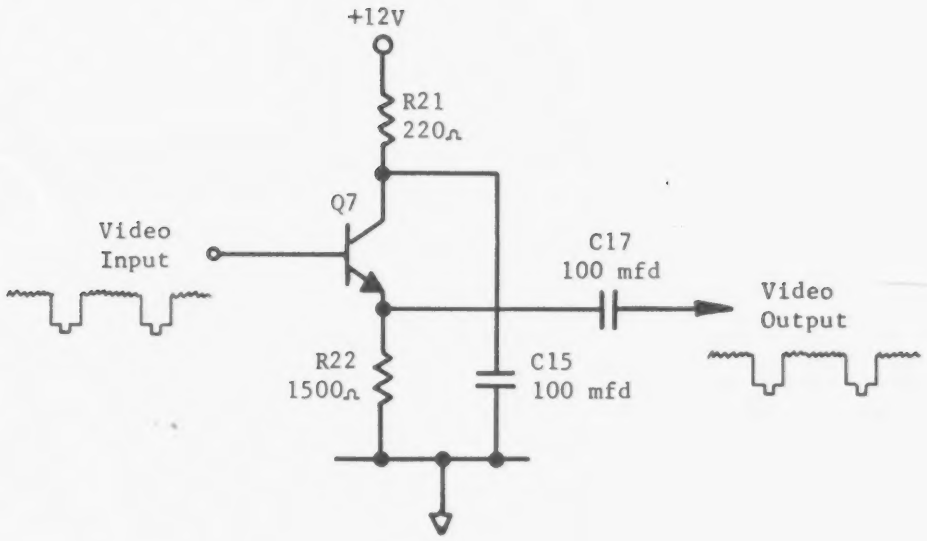


Fig. 13a—Schematic of original monitor circuit

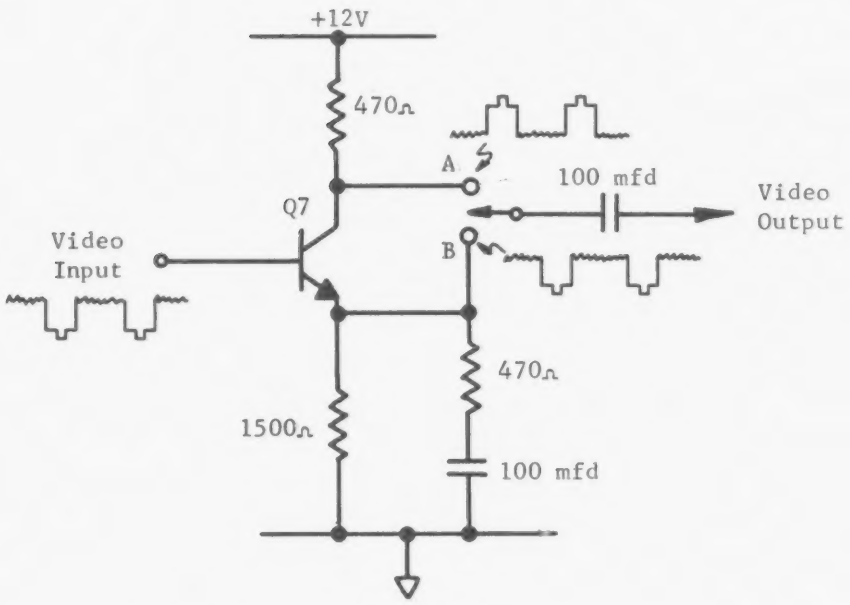


Fig. 13b—Schematic of monitor circuit showing initial modification for video reversal

Q7. Note that in going through transistor Q1 in Fig. 14a, the polarity of the signal is inverted so that the positive pulse applied at the input to this circuit appears as a negative signal at point A.

In a similar fashion, a horizontal blanking pulse was obtained from the emitter of transistor Q17. Because this pulse is of fairly high voltage, a resistance divider network, comprised of a 470-K resistor in series with a 22-K resistor, is used to attenuate the signal before it is applied to the base of the transistor shown in Fig. 14b. The output of this transistor is coupled through a 1-K resistor to point A, as was done with the vertical blanking pulse. Appropriately connected diodes might be used in place of R-3 and R-4.

The switch used for selection of either point A or B as the source for signals to the succeeding stages is mounted on the rear of the monitor case to keep the wires involved as short as possible. The final circuit with the changes described above is shown in Fig. 15. Its operation is as follows.

For normal contrast, the switch is in position B-B′, providing a signal with appropriate blanking as supplied from the camera to the video output stage. No further changes or additions are required. For contrast reversal, the switch is connected to point A-A′, where, as previously described, both the video as well as the blanking information from the camera are inverted. Thus, instead of blanking, the signal will tend to make the screen go bright at the time that retrace operations are occurring; however, at the same time, signals taken from the other points shown in Fig. 15 will turn transistor Q1 and Q2 on, that is, to a highly conducting state. These then pull the signal, appearing at the collector of Q7, down to approximately the normal blanking level. When these signals are not on, that is, when blanking is not

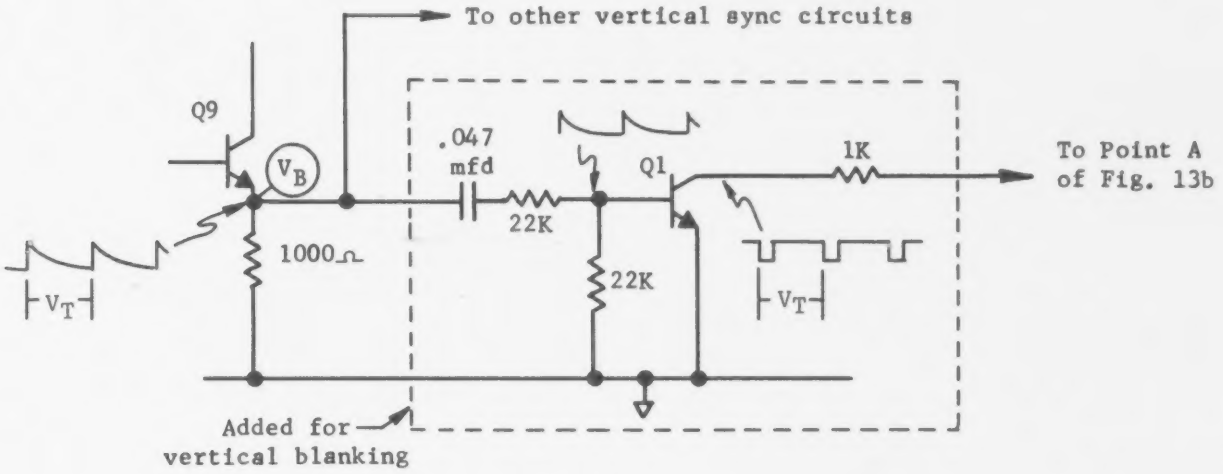
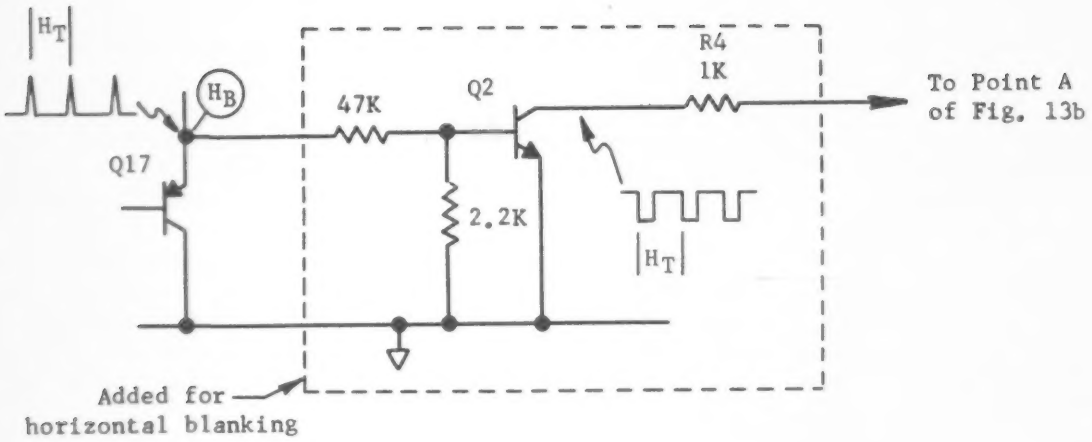


Fig. 14a—Schematic of circuit showing vertical blanking modification



$V_T \approx 16.7$ msec

$H_T \approx 62$ usec

Fig. 14b—Schematic of circuit showing horizontal blanking modification

occurring, transistors Q1 and Q2 are in effect open-circuited, and the resistors R-3 and R-4 have no effect on the signal.

Although this approach was the easiest one to implement at the time, it is not the most effective. It would be much better to accomplish this function in the camera, so that contrast reversal would be available in the RF output of the camera. Thus, contrast reversal would be available with an ordinary television receiver. Further, if two or more monitors are being used simultaneously, the monitor circuit changes must be made in each. If contrast reversal were carried out in the camera, a circuit change would have to be made only once.

An electronic window was later added to our Shibaden monitors. The effect of the window is to turn video off, except for a controlled period of time, so that portions of the top and the bottom of the screen are blacked out. This is accomplished by the circuit shown in Fig. 16. The negative going vertical sync pulse, appearing at the collector of Q9, is coupled through C-7 and triggers the monostable multivibrator M1 into an "on" state, during which the output on pin 1 is up. It remains in this "on" state until time T1, determined by the value of R-1 and C-1. At that time, M1 turns off and M2 turns on because the signal applied to pin 5 of M2 is negative going. M2 stays on until time T2 is determined by R-2 and C-2 and then it goes off. The signal on pin 6 is off when M2 is on and vice versa; therefore, on going through transistor Q3, it is applied as a blanking pulse to the output of Q7 as previously described.

Thus, blanking occurs after vertical sync until time T1, when the video signal is unblanked. At time T2, blanking occurs again until the entire sequence is re-

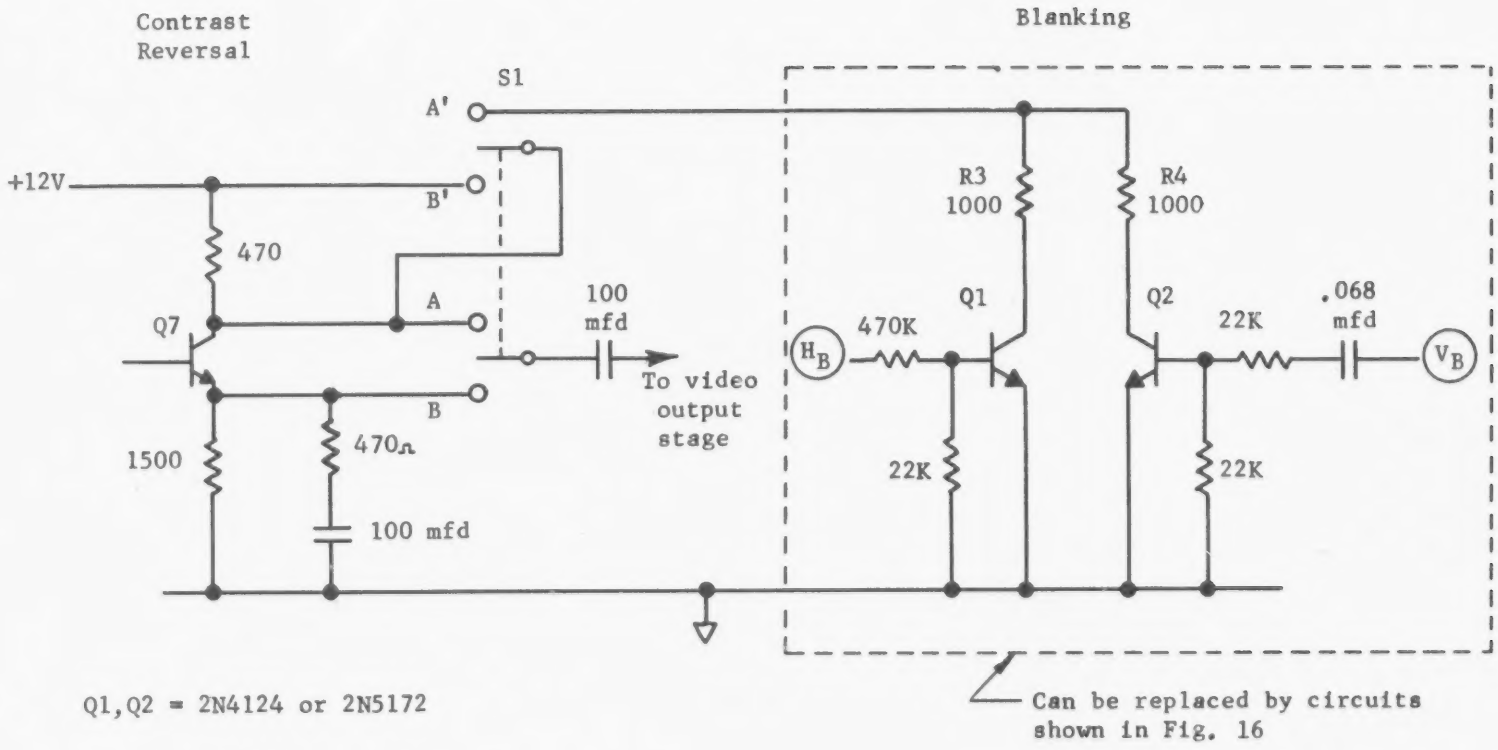


Fig. 15—Schematic showing contrast-reversal modifications to TV monitor

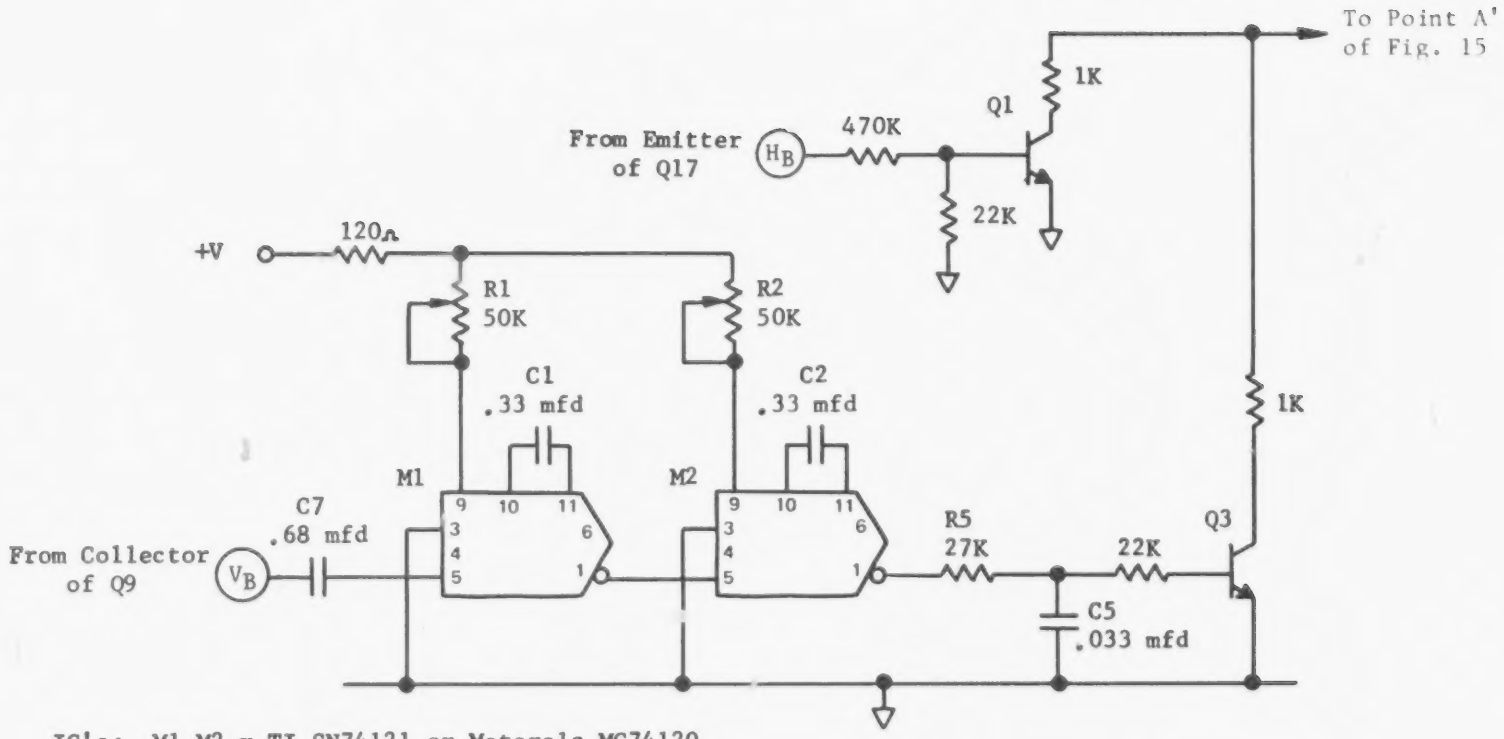


Fig. 16—Schematic of electronic window and horizontal blanking circuits

peated, namely, when vertical sync occurs again.[1] R-1 and R-2 are variable resistors mounted on the rear cover of the monitor, so the viewer has reasonable access to them. By varying R-1, the entire window moves up or down while R-2 changes the height of the window.

To slow up the turn-on and the turn-off of the window so that these transitions occur over several horizontal scan lines (i.e., the "soft window" described in Sec. VI), R-5 and C-5 in Fig. 16 were introduced.

[1] Note that, with the electronic window, vertical blanking is not required since window blanking overlaps vertical blanking.

Appendix D

VIDEO INFORMATION PROCESSOR CIRCUIT DETAILS

Some of the electronic details of VIP are shown in Fig. 17. At the input, the DC restore circuit diode D1 keeps the sync level at ground (in reality, at about .3 v due to diode gap voltage) to compensate for cameras that have an AC-coupled output. The emitter-follower Q1 isolates the input and drives the following stages. The differential amplifier Q2-Q3 provides a negative output at point A whenever the input signal falls below the value determined by the setting of potentiometer P1, which is normally set so output occurs when the input level falls to blanking potential. Thus, the negative pulse at A is as long as the entire blanking interval, either horizontal or vertical.

The vertical detector develops an output pulse only when a vertical blanking signal is present and ignores the shorter horizontal pulses. The signal at point A is also used to control the two video switches V1 and V2. When pin 2 of V1 is up, that is, at a positive voltage greater than about 3 v, the signal appearing on pin 1 is proportional to the difference between the signals applied to pins 3 and 4. The negative of the voltage appearing on pin 1 will appear on pin 7, providing an inverted video signal. When pin 2 is down (less than 3 v), the difference between the voltages on pins 5 and 6 will appear on pin 1 and its negative value on pin 7. Because pins 5 and 6 are grounded, the output from V1 is zero at that time. Thus V1 has an output (and its negative value) only during the time video information is present, and it has no output during horizontal or vertical blanking intervals. P2 can be used to vary the DC output level of the video signal.

The video switch V2, however, has zero output when video information is present because pins 3 and 4 are grounded, and it picks up the incoming sync and blanking signals on pins 5 and 6 when the gate on pin 2 is down. Thus, the incoming signal has been separated into two paths—one containing image information, the other containing only sync and blanking signals. Switch S1 selects either the normal contrast or reverse contrast. Potentiometer P3 can be used to select the amount of video signal to be applied to V3, thus providing an additional range of contrast enhancement. By separating the image and sync signals, various kinds of processing can be carried out on one without affecting the other.

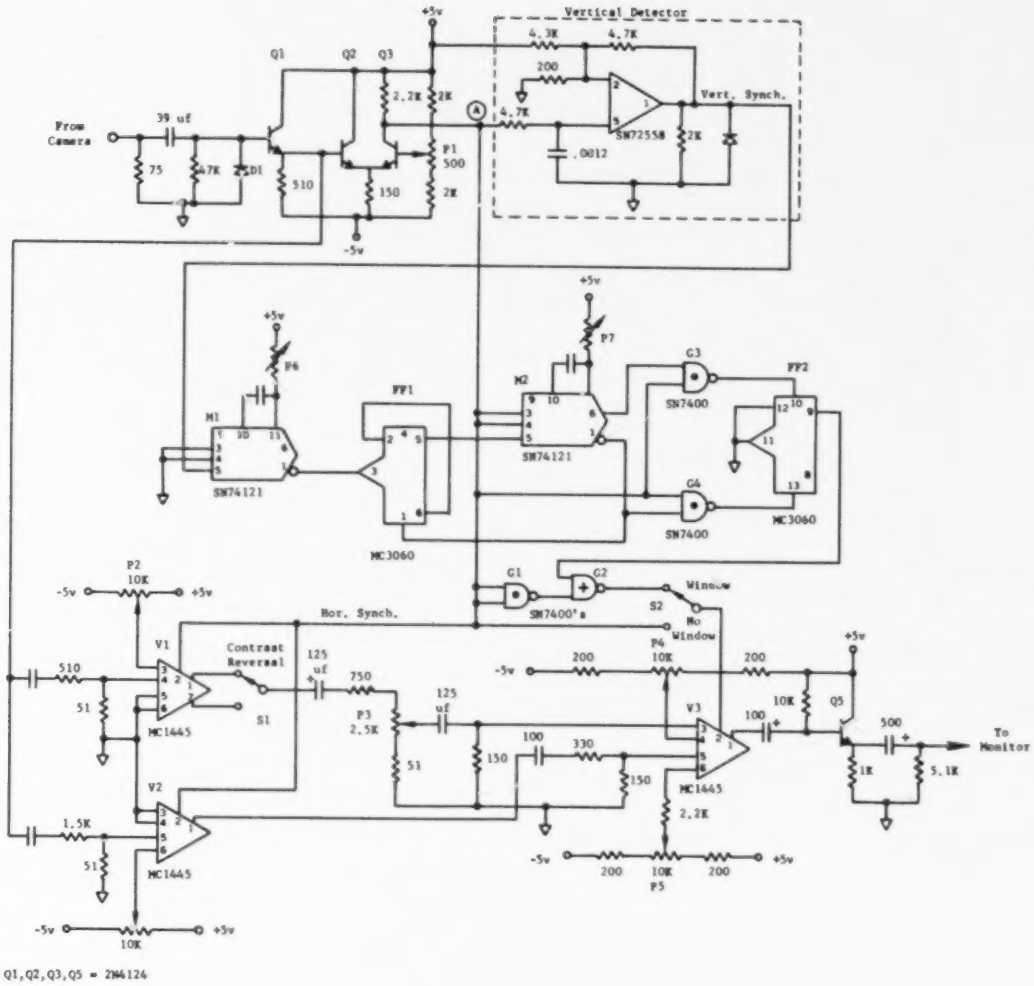


Fig. 17—Circuit diagram for the Video Information Processor

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Video switch V3 is used to mix the processed video from V1 and the blanking and sync information from V2. Potentiometers P4 and P5 set the corresponding DC levels in the resultant composite video on pin 1 of V3. This signal is then coupled to the emitter-follower Q5 that is used to drive the 75-ohm cable leading to the monitor.

To obtain the electronic window, multivibrator M1 is triggered on by the vertical blanking signal, and it stays on until time T1, determined by the setting of P6, when it goes off. Flip-flop FF1 goes on when M1 goes off and FF1 remains on. Multivibrator M2 goes on when both FF1 is on and a horizontal pulse occurs. When M2 goes on, it turns off FF1. M2 stays on until time T2, determined by the setting of P7. Logic elements G3 and G4 ensure that the output gate from FF2 goes on and off at the next horizontal sync time after T1 and T2, respectively. With switch S2 in the no-window position, the action of V3 is as previously described. With S2 in the window position, V3 continues to select only sync signals until time T1, when sync and video are both selected. At time T2, only sync signals are again selected.

P2, P4, P5, and P8 must all be adjusted to provide a balanced level for the composite video signal at the output. This adjustment is best done with an oscilloscope.